AER

AQUATIC ECOSYSTEM RESEARCH

A Freshwater Conservation Company

HIDDEN LAKE

MANAGEMENT OVERVIEW

PREPARED FOR THE
HIDDEN LAKE ASSOCIATION
HIGGANUM, CT
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Contents

INTRODUCTION

Hidden Lake is located in Higganum, Connecticut (41°25'16.2"N, 72°34'09.9"W) and has a surface area of approximately 41 acres. This man-made waterbody has a maximum depth of just less than 2.4 meters, a mean depth of 1.3 meters, with a total volume of approximately 206,000 cubic meters (45 million gallons). The waterbody is fed by a single unnamed tributary entering from the north, a smaller stream also entering at the northernmost point, and a combination with wetlands situated to the north and east. The lake spills over a small dam into Pond Meadow Brook. Pond Meadow Brook in turn flows into Chatfield Hollow Brook, and eventually to the Hammonasset River. Hidden Lake is located in the Chatfield Hollow Brook sub-region of the South Central Eastern watershed complex. The local watershed is roughly 760 acres (1.18 sq. miles), with a watershed to lake surface area ratio of 18.5.

In 2022 the Hidden Lake Association (HLA) contracted with Aquatic Ecosystem Research (AER) to perform an extensive bathymetric mapping and sediment analysis of Hidden Lake. In addition to this effort, the Association requested a holistic management plan to guide the association in stewarding the lake in the future. Of primary concern was the health of the waterbody, issues of sedimentation and water depth, and best practices moving forward.

MANAGEMENT TOPICS

Water Quality

The HLA has implemented several programs in the interest of the water quality of Hidden Lake. These included a mandatory pump-out and inspection program of on-site sewage disposal systems, aka septic systems. This type of program has been found to be effective at reducing the number of failing septic systems in an area that could impair water quality and create public health risks to recreational users of the lake (CLA 2002), and should be continued at Hidden Lake.

The HLA has also historically supported lake water quality monitoring initiatives. Early efforts were performed by Dr. Priscilla Baillie starting in the mid-1990s and continuing through 2006. Her past reports included field and laboratory water quality data, and bacteriological data.

More recently, the HLA implemented its own water quality monitoring program which involves sampling at seven sites in the lake twice each year. Data from the 2022 season provided to AER included results from analyses of phosphorus and *Escherichia coli* (aka E*. coli*) at each of the seven sites on June 20, 2022, and results of analyses of phosphorus and turbidity at one site on July 22, 2022. Phosphorus and bacteriological data were presumably collected at the same seven sites in 1993, 1994, and 1995, and reported on in Dr. Baillie’s 1995 report.

Two of the water parameters of interest from the historical data are phosphorus and specific conductance. Phosphorus is generally the nutrient that limits levels of algal productivity in freshwater systems. It is typically measured as total phosphorus, i.e., all phosphorus that is soluble (phosphate) and all that is in a particulate form (e.g., bound to sediment, in organic matter) in the open water. In some studies, the soluble phosphorus (phosphate) is also measured.

Phosphorus data collected by Dr. Baillie were initially from three sites, and then at one site in 2006 where depth was approximately two meters. Phosphorus concentrations from her samples were mostly <20 µg/L and indicative of mesotrophic conditions (Fig. 1).

The seven sites noted earlier most likely included the sites used by Dr. Baillie, but also included other more localized areas of the lake, e.g., North Cove, West Cove. Those sites were probably shallower and may have had higher density of aquatic plants. Aquatic plants can impact phosphorus levels since they can act as both nutrient sinks (taking in nutrients) and nutrient pumps (releasing nutrients). Lake phosphorus averages from the seven sites tended to be more variable and concentrations in many samples were >30µg/L, indicative of eutrophic conditions (Fig.1).

The important point here is that differences in sample collection protocols can results in differences in data interpretation. Therefore, it is important to develop consistent methods and adhere to them as best as possible. It is also a good practice to develop a quality assurance project plan (aka QAPP) or similar standard operating practice, so that methods are memorialized in writing. We highly recommend the development of a QAPP since it is useful in ensuring continuity of data when changeover of volunteers within lake monitoring groups occurs.

Conductivity is a surrogate measurement of the sum of the ionized minerals, metals, and salts in the water and measured in microsiemens per cm (µS/cm). It is a measure of water's ability to transmit an electrical current. Specific conductance is conductivity standardized to a set water temperature (25°C) since temperature influences conductivity and – in the field – temperature varies with depth and/or date.

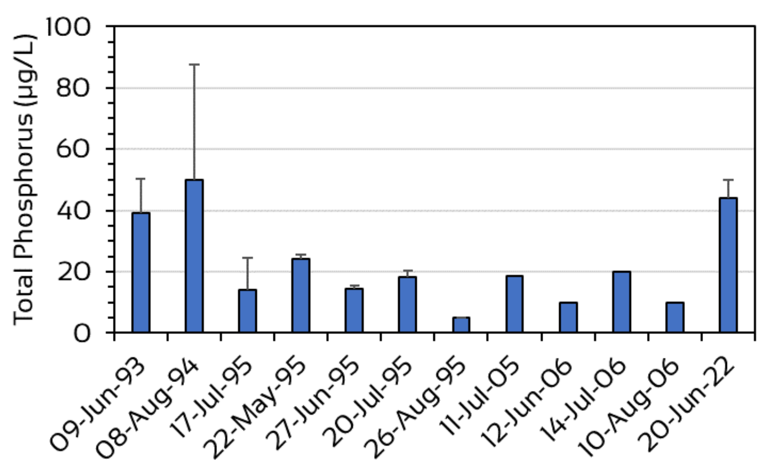

Figure 1: Phosphorus levels at Hidden Lake from 1993 through 2022. 09-June-93, 08-August-94, 17-July-95, and 20-June-22 are averages of seven sites. 22-May-95, 27-June-95, 20-July-95, and 26-August-95 are averages of three sites. The 2005 and 2006 data are from one site. Error bars are standard deviations displayed to reflect variability among sites on a given date.

Specific conductance is an important metric in limnological studies due to its ability to detect pollutants and/or nutrient loadings. Specific conductance can also have an influence on organisms that inhabit a lake or pond; particularly, algae. The composition of algal communities has been shown to be related, in part, to conductivity levels in lakes. Many lakes in Connecticut have seen a steady increase in specific conductance over time due to increased use of deicing salts on roadways. These increases are often due to salts (and other pollutants) being exported to the lake via stormwater runoff (Kelly et.al. 2019). For some public water supply reservoirs, specific conductance levels began to increase after 2008 (J. Hudak, pers. communication). This corresponds with a shift in CT Department of Transportation (DOT) practices in 2007, where salt is now exclusively used in winter storm events rather than a salt/sand mix.

Historical conductivity data for Hidden Lake was limited to that collected by Dr. Baillie in 1995, 2005, and 2006. Those data were converted to specific conductance using the following formula:

$$\frac{Measured\ Conductivity}{(1 + (0.0191 * (Temperature\ of\ sample - 25°C)))}$$

Temperature is in degrees Celsius and was available in Dr. Baillie's reports.

Average specific conductance for a sampling date was determined from measurements at three sites in 1995 and from the single deepwater site in 2005 and 2006. Based on those limited data, specific conductance over the 11-year period was most often between 60 and 70 µS/cm and not trending either up or down (Fig. 2). Those levels are considered low relative to specific conductance at other Connecticut lakes.

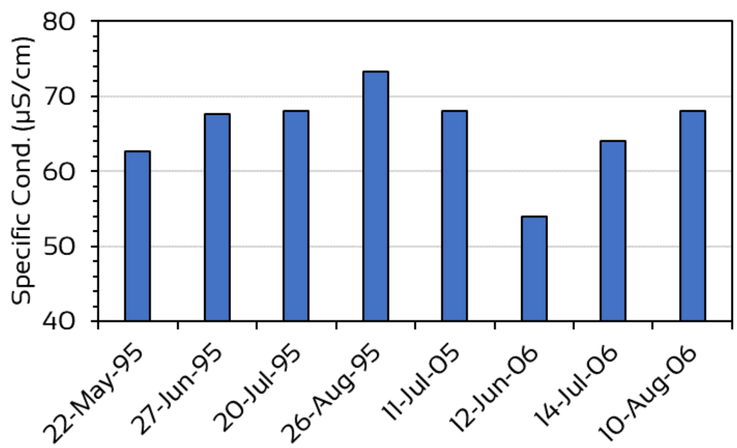

Figure 2: Specific conductance (Cond.) at Hidden Lake in 1995, 2005, and 2006.

The limited Hidden Lake specific conductance data suggests that there has not been an increased use of deicing salts on roads near Hidden Lake between 1995 and 2006. It also suggests that stormwater runoff may have played a limited role in water chemistry and sediment deposition in the lake during that time.

Given the widespread water quality impacts from road salt treatment practices in Connecticut since that time, additional specific conductance data collection is highly recommended.

As noted earlier, HLA has committed resources – both volunteer hours and monetary resources – into bacteriological monitoring of the lake. Early efforts used fecal coliform as the indicator organism. Connecticut now uses *Escherichia coli* (aka *E. coli*) as the indicator organism because it has been found to be a more effective indicator of fecal contamination than total coliforms and fecal coliforms.

The State of Connecticut provides guidelines for monitoring swimming waters and closure protocols (CT DPH & CT DEEP 2016). In that document it states, "*Samples should be collected at approximately 3 to 4 feet water depth*." The reasoning for the relatively shallow depth includes the closer proximity to the shoreline source and higher probability of dilution of bacteria in deeper waters due to mixing.

In the June 2022 data provided by the HLA, we noted that *E. coli* analyses were performed at the same seven sites where phosphorus was analyzed. For all seven sites, results from *E. coli* analyses were well below the threshold of 235 colonies per 100 mL. These data, along with the phosphorus concentrations at most sites on that date, raises the question of whether these sites are more representative of shoreline areas or open water areas. Site locations and depth should be evaluated relative to the water quality metric being analyzed and adjusted accordingly.

As recommended for water quality monitoring, we recommend memorializing bacteria sampling protocols in a QAPP.

Aquatic Plant Management

The first account of macrophytes (aquatic plant species) in Hidden Lake were those made by ACT (Aquatic Control Technology) in the 1980's. At the time, ACT recommended mechanical hydroraking to clear vegetation along the shoreline, where shorefront property owners were encountering recreational limitations due to plant growth. Limnologist Priscilla W. Baillie noted in many of her reports from 1990-2010 that *Nymphaea odorata*, *Nuphar variegata & Brasenia schreberi* (white water lily, yellow pond lily and watershield) tended to form dense mats across the coves. In 2005 and then again in 2018, CAES (The Connecticut Agricultural Experimentation Station) performed aquatic plant surveys of Hidden Lake. The latter survey (2018) showed that floating leaved plants (white water lily, yellow pond lily and watershield) had expanded into the central part of the waterbody. The 2018 CAES survey also documented a decrease in species diversity compared to the 2005 survey and various species lists laid out in earlier reports by Priscilla W. Baillie. The Lake Association currently operates a program where only "authorized" watercraft can be used on Hidden Lake. Watercraft bear a sticker authenticating that they are not used on other waterbodies.

As of 2022, the Hidden Lake Association has contracted with the Pond and Lake Connection to perform aquatic plant management activities on an "as needed" basis. The management goals are targeted towards keeping the deeper central basin clear of vegetation, specifically water lily species such as those listed above. The management regime also calls for allowing aquatic plants to grow along undeveloped shoreline areas and in the shallower coves. This is a sound strategy which balances the importance of maintaining an aquatic plant presence with recreational needs. It is important not to take a heavy-handed approach when performing aquatic plant management at any scale, and in this case, it appears that the management goals target critical areas while allowing areas of wildlife refuge to retain balance. Aquatic plants act as a sink for nutrients which might otherwise be absorbed by other primary producers such as algae. As Hidden Lake currently does not have issues with algae blooms, it is doubly important to maintain a healthy rooted plant population to provide natural nutrient sequestration.

Winter Drawdown

The Hidden Lake Association currently conducts a biennial drawdown of 3 feet to conduct shoreline infrastructure repairs and to remove near shore sediment buildup. The drawdown generally lasts 4-6 weeks and is commenced in the fall. Through communication with the Hidden Lake Association, it was determined that it generally takes the waterbody three to five days to refill following a normal drawdown

It is the opinion of AER that, while no drawdown is likely the ideal, the current practice is fairly benign. The biennial drawdown should be as shallow and as short as possible to achieve maintenance goals. While it was stated that a biennial drawdown is a part of the Associations bylaws, avoiding such a drawdown, when possible, may be beneficial to the goals of maintaining near shore plants in favor of managing deep water plants. Drawdowns of any depth can also increase sedimentation as littoral zone areas exposed while lake level is down are exposed to erosional forces (e.g., rain, wind, etc.). Those eroded materials are likely transported to deeper areas of the lake.

Sediment Accumulation

In 2022 AER was contracted by the Hidden Lake Association to conduct a bathymetric and sediment analysis of the waterbody. The bathymetric study utilized sonar depth data to generate a detailed bathymetric map, alongside side the sediment study where 90+ points were sampled with a stadia rod to determine the depth of soft and firm sediments. The full results of this undertaking are given in a 2022 Memo "Results from the Sediment Study at Hidden Lake". Management implications from the two main deliverables of the study are discussed below.

Sediment Mapping

A sediment map was generated and used to estimate sediment volumes. From discussion with the Hidden Lake Association board members, it was determined that a large-scale dredging project is outside the means of the Association. Therefore, a targeted approach is recommended utilizing historic quality data, collected sediment data, and field observations.

The most significant tributary to the waterbody enters at the northeastern cove. Field observations and orthophotography show significant deposition in this cove (Fig. 3). Additionally, it was noted that the northeastern shore receives runoff from agricultural fields, which could further contribute to sedimentation in the northern cove and eastern shore. At the tributary inlet, water depth was measured at 0.6 meters (2.0 feet) and soft sediment thickness was measured at 0.5 m (1.6 ft). Removal of this soft surface layer could enhance flushing from the entering stream, which would be beneficial for water quality. Removal of soft sediments at this smaller scale could serve as a long-term management goal for the association.

Figure 3: 2019 CT Aerial Photography showing sediment deposition at the main tributary inlet.

Bathymetry

Second, an interpolated bathymetric surface was compared to data collected by the Connecticut Agricultural Experiment Station (CAES). While the datasets were collected with varying methods, it was clear from that data that there was not significant loss of depth between 2002 and 2022. CAES utilized a transect based approach for measuring water depth. This method had several drawbacks: 1) water level was not included in the dataset; 2) GPS accuracy may have resulted in inconsistent sampling locations; and 3) sampling sites were not well distributed. Additionally, as previously noted, AER utilized a sonar based sampling technique, interpolating between points to create a seamless bathymetric map.

Despite these differences in collection methods, data from each year of CAES surveys (2002/2018) were compared to the most recent bathymetric data, as well as to each other. On a point-to-point basis, results were inconsistent, i.e., some sites showed increases in depth, while others showed decreases. From 2002 to 2022, on average there was a 0.18 meter (7.0 inches) ***decrease*** in depth. From 2018 to 2022 there was 0.22 meter (8.7 inches) ***increase*** in depth. This highlights the incompatibility and inability to directly compare these data. The collection in 2022 of two high quality sediment and bathymetric datasets will greatly improve the ability for future comparisons of this nature. From these ambiguous results, it does not appear that depth has declined substantially over the past two decades. The year-to-year differences and between the averages may be a simple matter of fluctuating water levels and spatial accuracy during the various sampling events.

Best Watershed Practices

AER performed a watershed land cover mapping analysis using 2016 data from NOAA's Coast Change Analysis Program (C-CAP) (Fig. 3, Table 1). Overall, Hidden Lake's 1.18 square mile watershed is sparsely developed, with the most intense development being the residential community around the lake itself. The long-term health of a lake, including water quality and aquatic communities, is largely a function of its watershed. Lakes characterized by low nutrient loading, infrequent nuisance algae blooms, and low sedimentation rates are generally associated with highly forested watersheds containing minimal impervious cover (<10 percent), such as roads, roofs, and parking lots. Hidden Lake's watershed is over 70 percent forested with about 6 percent impervious cover.

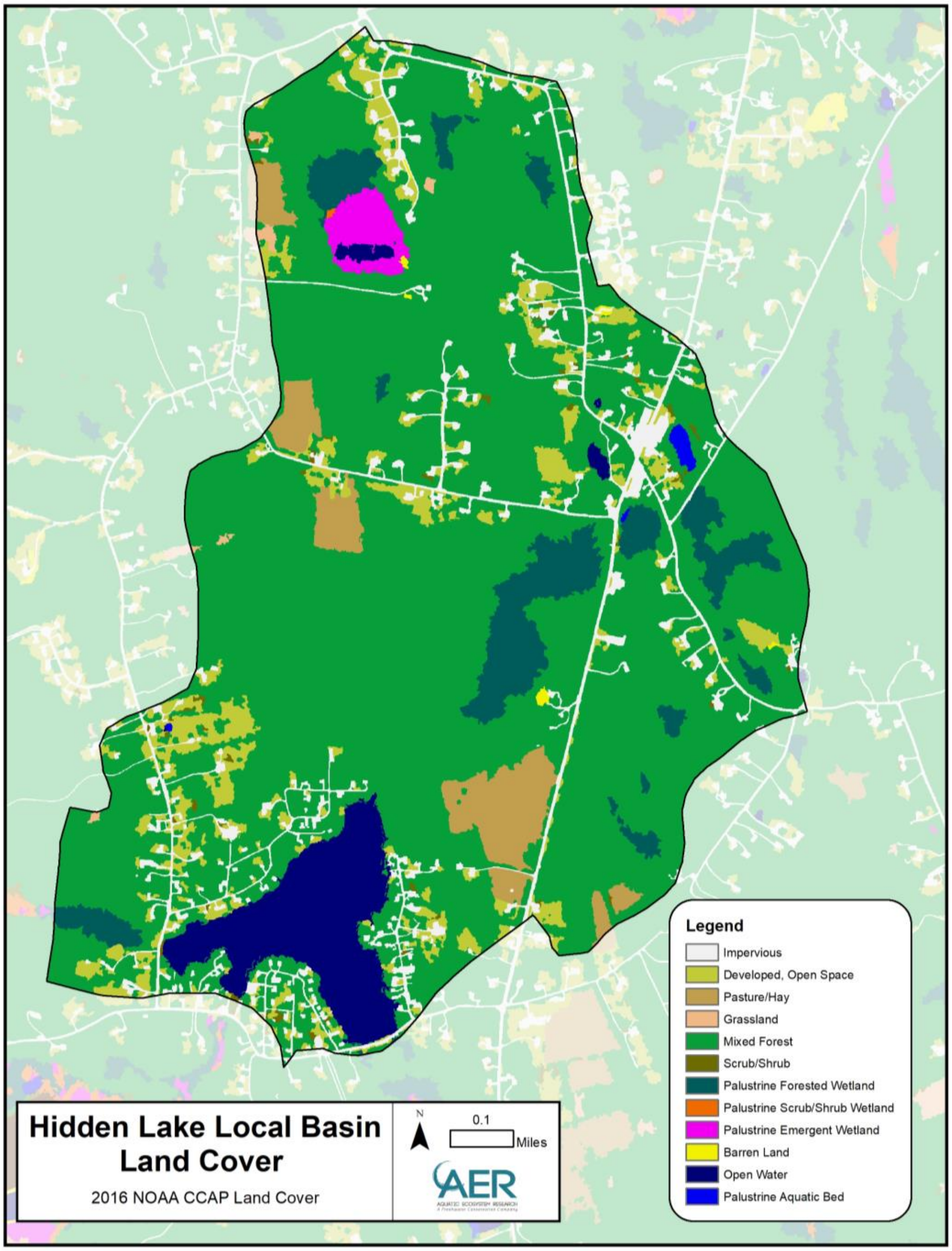

Figure 4: 2016 Land Cover Map.

Table 1: Watershed Land Use Characteristics.

Hidden Lake Land Cover - 2016 NOAA CCAP Data		
Land Cover	Area (acres)	Percent (%)
Impervious	47.3	6.2
Developed, Open Space	48.3	6.4
Pasture/Hay	28.2	3.7
Grassland	1.3	0.2
Mixed Forest	537.5	71.0
Scrub/Shrub	2.4	0.3
Palustrine Forested Wetland	42.2	5.6
Palustrine Scrub/Shrub Wetland	0.1	0.0
Palustrine Emergent Wetland	7.2	0.9
Barren Land	0.7	0.1
Open Water	40.9	5.4
Palustrine Aquatic Bed	1.3	0.2
Total	757.3	100.0

Although it is evident that Hidden Lake is well-managed and of high quality, water bodies throughout Connecticut are being stressed by emerging factors such as climate change and inputs of chlorides from road deicing products. Management and monitoring of this lake and its watershed should focus on 1) controlling potential adverse impacts from the residential development around the lake; and 2) monitoring both existing and potential future land use activities in the larger watershed that could degrade the current quality of the lake and its ecosystem. The Hidden Lake Association is currently implementing a number of Best Management Practices to promote the long-term viability of the lake, including:

- An ordinance requiring pumping of septic systems every four years;
- Annual cleaning of catch basins to ensure maximum sediment retention;
- Rebuilding several culverts and installing filter fabric to reduce sediment loading
- Controlling the introduction of invasive species by limiting use of outside watercraft and a sticker program to ensure cleaning of boats.

In addition to the above measures, the following would also be of benefit in minimizing nutrient and sediment loading from surrounding properties where not currently practiced:

- Limiting or prohibiting application of lawn fertilizers and pesticides;
- Establishing buffers with native vegetation along shoreline areas that currently consist of maintained grass lawns. Although, most of the lakeshore is currently forested, there may be opportunities for this along the southwestern portion of the lake, shown in the summer 2018 aerial image below (Fig. 5).

- Develop educational material and outreach programs to promote the use of living borders and buffer zones around the lake.
- Explore the possibility of relationships with companies that can provide reduced cost services to homeowners interested in buffer zone gardens.
- Develop and implement a "LakeSmart" program, incentivizing the key initiatives below:
    - Clean up after pets in a timely manner using proper disposal methods.
    - Avoid using storm drains to dispose of yard waste like leaves, grass, and debris.
    - Reduce or eliminate use of chemical fertilizers and pest control products; if necessary, use fertilizers with slow-release forms of phosphorus and nitrogen.
    - Create a vegetated buffer on the lakeshore and around the perimeter of a property to reduce pollutant-laden stormwater runoff.
    - Use trees, shrubs and groundcovers that are native to New England to improve odds of successfully establishing the "buffer gardens"; avoid planting invasive species.
    - Offset rainwater runoff from gutters with rain barrels, rain gardens, or dry wells.
    - Avoid using soaps and detergents that contain phosphates when working outside.
    - Consider picking up litter and floating invasive weed fragments.

Figure 5: Summer 2018 aerial Image of Hidden Lake southwestern shoreline (Source: National Agricultural Aerial Image Program (NAIP))

Monitoring and Recordkeeping

Water Quality

Consistent and timely data management is critical to lake conservation efforts. It provides lake stewards and managers a means to compare current data with historical data, determine variability within datasets, and detect significant changes within the lake system as a whole or within individual parameters, e.g., total phosphorus, over time.

Microsoft Excel is software commonly used to manage data. In Table 2, we have depicted a hypothetical Excel spreadsheet for Hidden Lake using data collected in 1995 and 2022 and provided to AER by the HLA. Typically, columns are used to represent the variables measured including date, site, depth, and physical (e.g., temperature) and chemical data (e.g., oxygen concentration, specific conductance). Each row represents a record of when all or some data is collected. Some variables will be populated with data each time data is entered, e.g., date and site samples were collected or measurements was made. Other variables may not always have data within a record.

Table 2: An example of a Microsoft Excel spreadsheet set up to manage Hidden Lake water quality day. This example uses data collected in the May of 1995, and June of 2022.

Date	Site	Depth (m)	Temp (°C)	DO (mg/L)	Cond. (µS/cm)	Sp. Cond. (µS/cm)	pH (SU)	Alk. (mg/L	Chl-a (ug/L)	Phaeo-a (ug/L)	NO3 (mg/L)	TP (mg/L)	Turb (NTU)	Secchi (m)	E. coli (col/100mL)
22-May-95	Station 1	0	18.6	9.2	55	63	6.91	15	5.99	1.17	0.03	0.023		1.8	
22-May-95	Station 1	0.5	18.5	9	54	62									
22-May-95	Station 1	1	18.1	9	54	62									
22-May-95	Station 1	1.5	17.5	9.9	54	63									
22-May-95	Station 1	1.9	16.8	6.3	54	64									
22-May-95	Station 2	0	18.2	8.9	55	63	6.84	15	5.38	1.08	0.024	0.025			
22-May-95	Station 2	0.5	18.1	8.7	55	63									
22-May-95	Station 2	1	18	8.8	56	65									
22-May-95	Station 2	1.2	18	8.2	56	65									
22-May-95	Station 3	0	19	9.1	54	61	6.85	15	3.52	0.61	0.023	0.025			
22-May-95	Station 3	0.5	18.8	9	55	62									
22-May-95	Station 3	1	18.2	8.8	55	63									
22-May-95	Station 3	1.5	18.1	9.3	55	63									
22-May-95	Station 3	1.6	17.9	8.1	58	67									
22-May-95	Inflow A		14.5	9.3	47	59	6.68	15			0.055	0.015			
22-May-95	Inflow B		14.9	9.7	29	36	6.75	15			0.062	0.053			
20-Jun-22	East Shore	1										0.040			6
20-Jun-22	South Cove	1										0.055			4
20-Jun-22	Shore Beach	1										0.035			4
20-Jun-22	West Shore Beach	1										0.050			2
20-Jun-22	Mill Bay (Dam)	1										0.044			6
20-Jun-22	West Cove	1										0.440			42
20-Jun-22	North Cove	1										0.043			2
22-Aug-22	West Cove	1											3.2		98

Variables for each record that are always collected, e.g., data, site, and depth, can be used to sort all of the data. For example, if someone wanted all of the phosphorus data collected at 1 meter of depth at all sites, he/she might sort the entire dataset first by depth (smallest to largest), secondly by site (A – Z), and thirdly by date (oldest to newest). This would group all data first by depth, then site, then date. All of the phosphorus data collected from samples at 1 meter of depth would be grouped and easily copied to use in statistical trend analyses.

In-depth studies on lakes may include multiple variables that are measured at multiple depths within the water column and measured multiple times in a season. Most studies include "limiting nutrient" data, i.e., the nutrients that are least available to algae relative to metabolic needs. In most freshwater systems, that nutrient is phosphorus. In most studies it is measured as total phosphorus and in samples collected close to the surface (approximately 1 meter) and near the bottom (approximately ½ to 1 meter from the bottom).

Table 3: Critical and important water quality variables that should be incorporated into the Hidden Lake water quality monitoring program. Units refer to how the data is usually reported. MDL is the Method Detection Limit and refers to the lower limit of detectability based on the methodology. Depth refers to where in the water column the samples should be collected.

Variable	Units	MDL	Depths
Critical Water Quality Variable			
Total Phosphorus	µg/L	0.005 mg/L	1m below surface; ½m above bottom
Secchi Transparency	meters	NA	NA
Temperature	°C	0.5°C	½ m below surface; 1m intervals to bottom
Dissolved Oxygen	mg/L	1 mg/L	½ m below surface; 1m intervals to bottom
Specific Conductance	µS/cm	2 µS/cm	½ m below surface; 1m intervals to bottom
Important Water Quality Variables			
Variable	Units	MDL	Depths
Total Nitrogen (TKN + NOx)*	µg/L	0.02 mg/L	1 m below surface; ½m above bottom
pH	pH SU	0.1 pH SU	1 m below surface; ½m above bottom
Alkalinity	mg/L	1.0 mg/L	1 m below surface; ½m above bottom
Base Cations	mg/L	0.5 mg/L	1 m below surface
Chloride	mg/L	1.0 mg/L	1 m below surface
Chlorophyll-a	µg/L	0.001 mg/L	1 m below surface or integration of top 3m

The nutrient that is usually most limiting of algae growth after phosphorus is nitrogen. Like total phosphorus, total nitrogen is also commonly used to assess the amount of productivity the lake will support and is the sum of nitrates, nitrites and total Kjeldahl nitrogen (TKN) – the nitrogen in organic compounds, including proteins. Ammonia is a nitrogen compound measured as part of TKN, but is often also measured independently.

Two other variables used to assess the trophic state of a lake are Secchi disk transparency and chlorophyll-*a* concentration. Secchi disk transparency is a measure of how well or how poorly light transmits through the water column. Lakes with high Secchi transparency generally have low algal cell concentrations in the water column, while low Secchi transparency is indicative of high algal cell concentrations, particularly blue-green algae (aka cyanobacteria). Chlorophyll-*a* is the photosynthetic pigment common to all algae, is used in photosynthesis, and is an excellent surrogate of algal biovolume in the water.

In addition to the trophic-related variables, there are a number of physical and chemical variables routinely measured in lake monitoring programs. For example, pH and alkalinity are often measured to understand the acidity and acid neutralizing capacity of lake water. Temperature and dissolved oxygen concentrations throughout the water column are routinely measured in these types of undertakings.

As noted above, conductivity and specific conductance are indicative of the dissolved salts, metals, and minerals in the water, are important for a range of reasons, and are often included in lake studies. In some instances, the prominent constituents of conductivity are measured separately in addition to conductivity. These include the positively charged sodium, potassium, calcium, and magnesium, and the negatively charged chloride, sulfate, and the alkalinity ions.

Table 3 provides water quality variables we consider critical to water quality monitoring, and those we would characterize as important.

Equipment

Some volunteer lake monitoring groups evolve to the point of purchasing field equipment and instrumentation to improve upon their ability to monitor their lake. Equipment varies from simplistic and inexpensive like a Secchi disk and meter stick used to measure transparency, to much more expensive multiprobe instrumentation to measure temperature, dissolved oxygen, and conductivity and/or specific conductance throughout the water column.

We would encourage the HLA to consider planning to purchase field equipment over the next five years.

- Multiprobe. This instrumentation includes sensors or probes within a housing (aka sonde) attached to length of cable with a PDA to display and/or record data at various depths. Some systems connect to a blue-tooth / battery devise which conveys the data to a tablet or mobile phone with the manufactures app. Temperature, dissolved oxygen, and conductivity probes should be the minimum configuration within the sonde. Many include a depth sensor, with more costly sensors available to measure turbidity, and chlorophyll-*a* and cyanobacterial pigment fluorescence
- Secchi disk. This is a black and white, 20 cm diameter disk attached to a line that is used to measure transparency of the water. The meter stick is used to measure how far the disk was lowered with a line before visual contact was lost. Alternatively, the line can be marked at one-meter intervals.
- Sampling Bottle. A horizontal sampling bottle allows the user to collect water samples at multiple depths in the water column
- Garmin GPS. This devise allows the user to collect a waypoint for each sampling location and return to the same point with a high degree of accuracy.

Table 4 provides links to lake monitoring equipment websites that provide descriptions and pricing.

Table 4: Sampling equipment examples.

Equipment / Instrument	Example Products and Pricing
Multiprobe instrument (e.g., Yellow Springs Instruments, Eureka Water Probes, Hydrolab) to measure temperature, dissolved oxygen, conductivity and/or specific conductance	https://www.ne3inc.com/ysi https://www.waterprobes.com/multi-probes-sondes-water-quality-monitoring https://www.otthydromet.com/en/about/our-brands/hydrolab
Secchi disk and meter stick	https://www.forestry-suppliers.com/p/77179/67171/fieldmaster-student-secchi-disc https://www.forestry-suppliers.com/p/71163/meter-stick
Sampling Bottle	https://www.neobits.com/wildco_623_2310_fieldmaster_basic_water_bottle_p10117483.html?atc=gbp&gclid=EAIaIQobChMI-NCRksHy_QIVRnxvBB1Aag8CEAQYByABEgITSPD_BwE
Garmin GPS	https://www.garmin.com/en-US/p/87768

Baseline Algae

It is often valuable to have an understanding of the algal community within a lake. The planktonic algae (aka phytoplankton) are responsive to water quality conditions. The phytoplankton community in clearer lakes, with low nutrient levels are often dominated by green algae, golden algae and diatoms, with turbid lakes with high nutrient levels are dominated by blue-green algae (cyanobacteria), some of which are now know to produce toxins.

A baseline assessment should include samples collected in the spring, summer, and fall as the community composition and cell concentrations naturally change over the course of the season. A baseline assessment should be performed by a microscopist with expertise in algal taxonomy.

Sampling Sites, Frequency, and Variables

As noted early, water quality and bacteria monitoring at Hidden Lake has exhibited a variety of forms over the decades, e.g., five sites vs. three sites vs. one site; monthly vs twice a season, etc.

As recommended earlier, there is a need to evaluate and adjust site locations based on what is being analyzed. For example, the bacteriological monitoring sample sites should be in no more than three to four feet of water. If they are not, then an adjustment is warranted.

Monitoring *E. coli* levels is certainly in the interest of public health. However, to only monitor once early in the season and once late in the season does not address how quickly conditions can change during the season. Public beaches on Connecticut lakes are monitored weekly by State or local government agencies. If the public health of the recreational public is the goal, then increasing the frequency of monitoring is recommended.

E. coli testing is also used in a related way, i.e., as an indicator of failing septic systems. It should be noted that *E. coli* have been used in conjunction with other indicators to detect failing septic systems. The US Geological Survey has published research on the feasibility of other septic input indicators, e.g. boron, chloride, and specific conductance (Hyer 2007). In a diagnostic feasibility study at Candlewood Lake, boron and artificial sweeteners were used to trace septic influences in lake water (Lombardo Associates 2020)

Water quality monitoring is typically performed not at shallow shoreline sites, but rather, at deep-water sites. For a waterbody the size of Hidden Lake, one or two sites should be adequate. If one site, then a site of maximum depth should be located using the bathymetric map AER provided. The depth at that site should be confirmed by sounding with a weighed field tape or dropline. An electronic depth or fish finder may also be used for this purpose. After confirming depth, the coordinate for the sites should be recorded with a GPS unit to ensure the same site will be sampled on subsequent dates. If a second site is used, it should be located outside of the main tributary in the north end of the lake.

A goal of the HLA should be to expand the monitoring program to include those "Critical Water Quality Variables" listed in Table 2. For temperature, dissolved oxygen, and conductivity as measured at regular intervals down the water column (e.g., at ½ meter, at 1 m and every meter afterwards until ½ meter from the bottom), a multiprobe instrument will be needed. Water samples collected for analysis of total phosphorus should be collected at 1 meter of depth, and ideally ½ meter above the bottom. Samples should also be collected for analyses of conductivity if the HLA is unable to purchase a multiprobe or handheld device with temperature and conductivity. The commercial laboratory performing analyses will need to also measure the temperature of the sample at the time when conductivity is measured to determine specific conductance.

In conjunction with our early recommended reduction of sites for total phosphorus sample analyses, we also recommend expanding the frequency to early, mid, and late season sampling for total phosphorus and conductivity.

Watershed

The Association should maintain centralized documentation and photographs of watershed management measures, monitoring data, and observations/notes during episodic events affecting the lake, such as:

- Dates of catch basin inspections/cleanouts and measurements of sediment and debris accumulation;
- Algae blooms;
- Newly detected plant species;
- Abnormally high turbidities in the lake or incoming tributaries. This is most likely to occur after extreme storm events. Watershed surveys should be conducted in these instances to determine likely upstream sources, such as construction, agriculture, or other soil disturbances.

Even with state-of-the-art lake and shoreline management, it is possible that future degradation of Hidden Lake could be brought about by activities on watershed properties outside the control of the Association. Maintaining awareness of proposed applications for development and ongoing land use activities within the entire watershed can be a vital tool for avoiding permanent adverse impacts to the lake and its ecosystem. Agendas and minutes of the Haddam Planning and Zoning Commission, Inland Wetlands Commission, and Zoning Board of Appeals can be found on the Haddam town website. Key areas of focus in reviewing plans for development include expansion of impervious cover (roads, parking lots, etc.), stormwater management (including pretreatment and maximizing on-site infiltration), buffers to streams and wetlands, erosion and sedimentation control during construction, and deicing practices. Any concerns during the application or construction process should be brought to the attention of the appropriate Commission chair and/or town staff member.

RECOMMENDATIONS

Water Quality:

- Develop a standardized water quality and bacteria monitoring program and memorialize these protocols in a Quality Assurance Project Plan (QAPP) or similar document;
- As financial resources allow, incorporate first the critical water quality variables at one or two sites, and several times a season (early season, mid-season, late season);
- Evaluate E. coli testing sites and adjust accordingly. Consider sampling more frequently;
- Compile all existing water quality and waterbody datasets, expand on this compilation with future data;
- Assess trends and variability within future and current datasets.

Plant Management:

- Continue management of aquatic vegetation situated in the central “deep water” basin, as well as high use shoreline areas to maintain recreational access;
- Utilize mechanical methods for removal of plants in shallow areas as possible. Mechanical methods will remove organic material from the waterbody rather than allowing degradation/sedimentation;
- Retain plant assemblages in undeveloped shoreline areas and coves;
- Conduct a waterbody-wide third-party plant survey to assess community health; a horizon of once each decade is recommended;
- Continue with watercraft inspection program to limit the possibility of invasive plant introduction.

Drawdowns:

- Conduct drawdowns of consistent depth and duration;
- Reduce the frequency and duration of drawdowns to “as necessary” to retain shallow water plant species.

Sedimentation & Bathymetry:

- Conduct periodic intensive bathymetric/sediment surveys using comparable methods to the 2022 initiative to assess basin depth. A horizon of once each decade is recommended.
- When conducting catch basin maintenance, monitor and record catch basin sediment accumulation.

Watershed:

- Develop a “LakeSmart” program (i.e. Beseck Lake, Lake Pocotopaug) to educate homeowners on practices to protect the water quality and ecosystem of Hidden Lake;
- Work with shoreline landowners and/or landscaping companies to establish native vegetation buffer zones and gardens on shoreline properties;
- Limit or prohibit use of fertilizers and pesticides by Association homeowners;
- Monitor existing and proposed land use activities in the larger watershed. Communicate concerns or comments to local land use officials.

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