Lake Nipmuc Baseline Assessment

Mendon, Massachusetts

PREPARED FOR
Town of Mendon
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Project No. M410-000
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1.0 INTRODUCTION

ESS Group, Inc. (ESS) was contracted to conduct a baseline assessment of Lake Nipmuc. The purpose of this project was to evaluate the condition of the lake and develop a list of potential management options and next steps on behalf of the Town of Mendon (Town).

The Lake Nipmuc Baseline Assessment report includes the following key elements:

- Description of project approach.
- Review of geographic setting and existing conditions.
- Identification of potential management issues.
- Presentation of management options for consideration.
- Identification of next steps.

2.0 PROJECT APPROACH

ESS's approach for this project involved the evaluation of existing data sources, as well as the collection of field data to address basic physical, biological, and water quality data gaps. The approach for each is described in the following sections. A summary of field visit dates and activities is provided in Table A.

2.1 Bathymetry

ESS completed a field visit to Lake Nipmuc on April 28, 2021 to map bathymetry (water depth) in the lake. Bathymetry was mapped using a single-beam echosounder (for deeper open water areas) and a sounding rod (for shallow, or weedy areas) to collect water depth measurements at 142 positions. An additional 143 locations were mapped on June 7, 2021 to provide greater detail in areas of complex bathymetry. The horizontal location of each bathymetric measurement was recorded in the Massachusetts State Plane (feet) coordinate system using a Trimble Geo7X Differential Global Positioning System (DGPS) capable of sub-meter accuracy with post-processing.

2.2 Biology

The biological assessment included mapping of aquatic plants, with a focus on identification of the extent and density of exotic and nuisance species. Additionally, ESS collected phytoplankton samples (algae) and opportunistically observed wildlife.

Aquatic Plants

ESS completed a field visit to Lake Nipmuc on June 7, 2021 to map aquatic plants in the lake. Plant rakes and direct observation were used to map the aquatic vegetative community composition, as well as cover and biovolume at 143 locations in Lake Nipmuc. All vascular aquatic plants were identified to genus or species level in the field by qualified staff. Percent cover and biovolume were visually ranked using the following scale:

- 0 = 0% (no cover)
- 1 = 1-24%
- 2 = 25-49%
- 3 = 50-74%

- 4 = 75% or more.

All observed species, percent cover, and biovolume were recorded at each point and positions were collected with a sub-meter accurate Trimble Geo7X GPS receiver.

Phytoplankton

ESS collected a phytoplankton sample from the deep hole of Lake Nipmuc on September 13, 2021. The sample was a depth-integrated composite of van Dorn grabs collected from the top 20 feet (6 m) of the water column.

The sample was field-preserved with Lugol's solution and stored in an opaque bottle, then shipped to Aquatic Analysts of Friday Harbor, Washington for analysis.

Wildlife

ESS noted opportunistic observations of turtles, fish, and other water-dependent wildlife during each field visit, with a focus on potential nuisance species, such as Canada Goose (*Branta canadensis maxima*)

2.3 Water Quality

In total, ESS completed four rounds of water quality sampling at Lake Nipmuc. The target areas and dates for each round of monitoring are summarized in Table A.

ESS assessed water quality at Lake Nipmuc in three primary areas:

1. Surface water, including inflows from the watershed, nearshore (Town beach) and outflows
2. In-lake at deep hole
3. Groundwater inflows

Sampling locations for each of these are depicted on Figure 1.

Surface Water

Surface water inflows included both dry and wet weather sampling events. Data collected during each round of surface water inflow included the following:

- Storm volume and duration (for wet weather samples only)
- Approximate discharge (flow), where relevant
- Observations of nearby resident waterfowl or wildlife that may serve as a source of pollutants
- Observations of septic breakouts, point sources, or other signs of potentially significant pollutant sources
- Description of sample appearance (e.g., color, cloudiness, odor)
- Water temperature

- Specific conductance
- Pathogen indicators (*E. coli*)
- Total phosphorus
- Total nitrogen (nitrate-nitrogen, nitrate-nitrogen, and total Kjeldahl nitrogen)

In-Lake Deep Hole

Data collected during in-lake water quality sampling events included the following:

- Vertical profile at 1-meter intervals from the surface to the bottom of the deep hole
  - Water temperature
  - Dissolved oxygen
  - Specific conductance
- Lake surface
  - Transparency (Secchi disk depth)
  - pH
  - *E. coli*
  - Total phosphorus
  - Total nitrogen (nitrate-nitrogen, nitrate-nitrogen, and total Kjeldahl nitrogen)
- Lake bottom
  - pH
  - *E. coli*
  - Total phosphorus
  - Total nitrogen (nitrate-nitrogen, nitrate-nitrogen, and total Kjeldahl nitrogen)

Groundwater Seepage

Groundwater seepage sampling consisted of two components: seepage rate and water quality. These components were measured along four shoreline segments. Three of the segments (GW-1, GW-3, and GW-4) were located in areas of more intense shoreline development, a proxy for potentially higher levels of septic loading. One of the segments (GW-2) was located along a less developed shoreline to provide an estimate of background pollutant concentrations in shallow groundwater.

Seepage rates were measured by installing eight seepage meters (i.e., two per shoreline segment) upon arrival at the lake. Each seepage meter consisted of a sealed cylinder that is installed several inches into lake sediments and a connected bag that is primed with a known quantity of water. The only pathway for water to enter or leave the seepage meter was through lake sediments. Seepage meters were left in place for approximately four hours. At the end of the four-hour period, the volume of water in each connected bag was re-measured. Increases in volume represented net inseepage from groundwater into the lake. Decreases in volume represented net outseepage from the lake to groundwater.

Shallow groundwater was extracted from lakeshore sediments using a littoral interstitial porewater (LIP) sampler. Field measurements of this water for temperature, pH, and specific conductance were compared to similar measurements of surface water in the lake. This process was used to confirm that the LIP sampler was collecting a sample representative of groundwater sources. In general, groundwater temperature, pH, and specific conductance would be expected to differ between surface and groundwater sources during a summer sampling event.

Water quality samples collected during the September 13, 2021 groundwater seepage survey were sent to the laboratory for analysis of the following analytes:

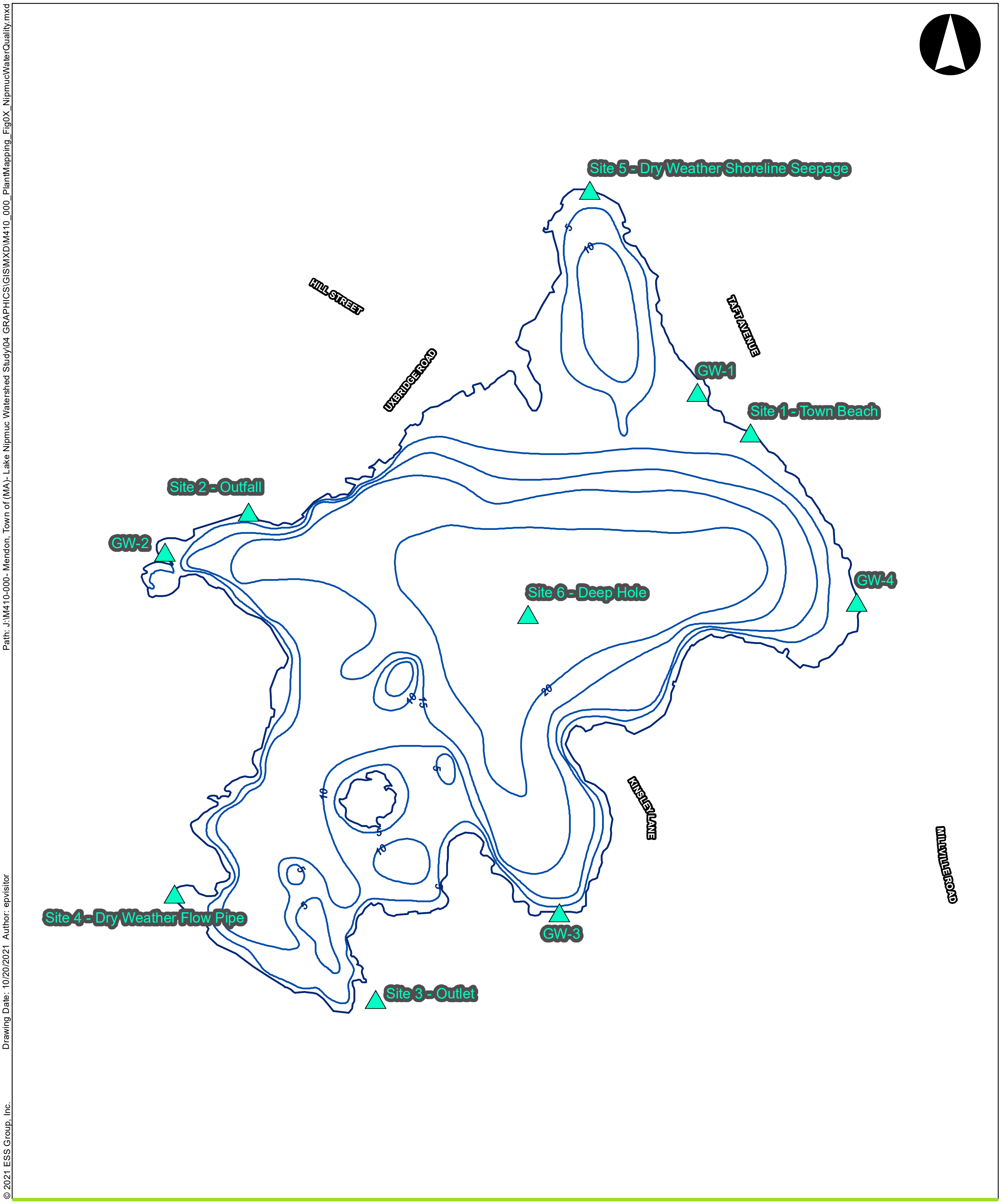
- Dissolved phosphorus
- Dissolved inorganic nitrogen (ammonia-nitrogen and nitrate-nitrogen)

The surface water sample and groundwater sample with the highest nitrate-nitrogen concentration were sent to IsoTech Laboratories of Champaign, Illinois for analysis of stable nitrogen isotopes of nitrate. The intent of this analysis was to help support the assessment of septic loading as a potential source of nitrogen to Lake Nipmuc, as opposed to other sources (e.g., fertilizer).

Table A. Summary of Data Collected during Field Visits to Lake Nipmuc in 2021

Date	Water Quality				Bathymetry	Aquatic Plants	Phytoplankton
	Dry Weather Surface	Wet Weather Surface	In-Lake at Deep Hole	Groundwater			
April 28			X*		X		
June 8			X*		X	X	
June 25	X						
July 12		X					
September 13			X	X			X

*In situ water quality measurements only



0 260 520 Feet

Lake Nipmuc
Mendon, MA

Source:
1) Esri, World Imagry, 2019
2) ESS, Field Surveys April & June 2021

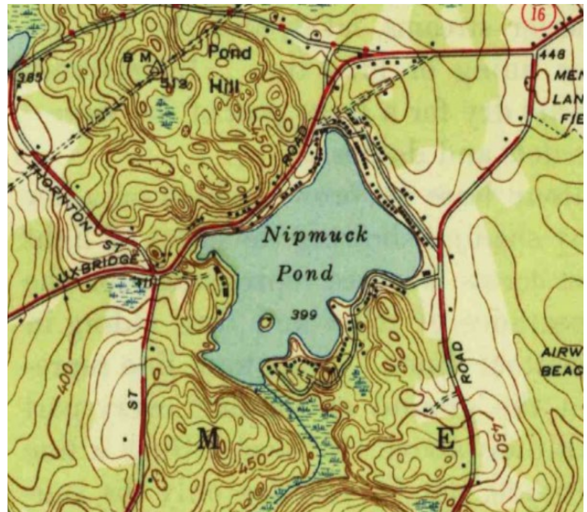
Water Quality Sample Location
Bathymetry Depth Contour (5 Ft Interval)

Lake Nipmuc Bathymetry and Water Quality Sampling Locations

Figure 1

3.0 EXISTING CONDITIONS

3.1 Setting



1944 USGS topographic map depicting Lake Nipmuc

Lake Nipmuc, also known as Nipmuc Pond or Nipmuck Pond, is an 87-acre Great Pond located entirely in the town of Mendon, Massachusetts. The lake forms the headwaters of Meadow Brook (a tributary to the Blackstone River) and there are no perennial tributaries. The contributing watershed is small (333-acres) relative to the lake and underlain by thin glacial till and bedrock. According to USGS StreamStats, 35 percent of the watershed is covered by forest, 26 percent is water, and 2 percent is wetlands. The remaining 37 percent is developed, primarily residential and commercial land uses. Route 16 (Uxbridge Road) is the only state highway in the watershed and borders much of Lake Nipmuc to the north.

Lake Nipmuc is listed by the Massachusetts Department of Environmental Protection (MassDEP) as a Category 3 water body, which means that no uses have been officially assessed by the state. However, the draft 2018/2020 Integrated List of Waters labels the lake with an "Alert" status based on unconfirmed reports of non-native aquatic macrophytes (variable-leaf milfoil [*Myriophyllum heterophyllum*]). Pursuant to 314 CMR 4.06 Lake Nipmuc is a Class B water body, which is "designated as a habitat for fish, other aquatic life, and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation...[Additionally,] Class B waters shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses. These waters shall have consistently good aesthetic value."

3.2 Bathymetry

Based on bathymetry data collected as part of this study, the maximum depth in Lake Nipmuc is approximately 25 feet with an average depth of 10.5 feet. The lake consists of two basins (Figure 1). The primary central basin constitutes approximately 75 percent of the lake area and contains the deepest water, although the southwestern portion of this basin is fairly shallow (less than 15 feet deep) and punctuated by an island and several shoals or obstructions. A second, smaller basin is located at the north end of the lake. This basin is distinctly separated from the main basin by an area of very shallow water (less than 5 feet deep) and forms a narrow, protected cove with a maximum depth of approximately 12 feet.

3.3 Biology

Phytoplankton

The integrated depth sample collected from Lake Nipmuc contained low densities of phytoplankton in the water column on the day of sampling (Table B). Neither algal nor cyanobacteria bloom conditions were evident, although several species of cyanobacteria were present at sub-bloom densities. The cryptomonad *Cryptomonas erosa* was the most abundant species observed in the sample. Other taxa groups observed in this sample included diatoms, euglenoids, golden algae, and green algae.

Table B. Phytoplankton Collected from Lake Nipmuc

Group	Taxon	Abundance
Bacillariophyceae (Diatoms)	*Achnanthes minutissima*	Least Abundant
	Cyclotella ocellata	Most Abundant
	Fragilaria crotonensis	Least Abundant
	Gomphonema subclavatum	Least Abundant
	Nitzschia frustulum	Least Abundant
	Synedra radians	Common
	Synedra rumpens	Least Abundant
	Synedra ulna	Uncommon
	Tabellaria fenestrata	Common
Chlorophyceae (Green)	*Ankistrodesmus falcatus*	Common
	Crucigenia quadrata	Uncommon
	Sphaerocystis schroeteria	Uncommon
Chrysophyceae (Golden)	*Dinobryon bavaricum*	Most Abundant
	Mallomonas sp.	Least Abundant
Cryptophyceae (Cryptomonads)	*Cryptomonas erosa*	Most Abundant
	Rhodomonas minuta	Common
Cyanobacteria (Blue-green)	*Anabaena flos-aquae*	Most Abundant
	Aphanizomenon flos-aquae	Common
	Aphanothece sp.	Uncommon
	Microcystis aeruginosa	Most Abundant
Euglenophyceae (Euglenoids)	*Trachelomonas scabra*	Least Abundant
	Trachelomonas volvocina	Uncommon
Overall		**Low Density (<5,000/mL)**

Abundance categories align with quartiles based on counts, as follows: Fourth Quartile = Most Abundant, Third Quartile = Common, Second Quartile = Uncommon, First Quartile = Least Abundant

Aquatic Vegetation

Aquatic vegetation was common but not excessive in most of Lake Nipmuc, with plant growth occurring in approximately 49 acres (56%) of the lake, primarily in areas less than 20 feet deep (Figures 2 and 3).

Where aquatic plants were found, cover was generally sparse (i.e., 25% cover or less), except for a few patches of moderate to dense growth located mainly in the northern sub-basin and protected coves along the western shoreline (Figure 2).

Aquatic plant biovolume was very low in the vast majority of Lake Nipmuc, with the exception of approximately 1 acre (1%) in some of the most protected coves (Figure 3).

The aquatic plant community in Lake Nipmuc consisted of 15 species, 3 of which are invasive species (Table C). Each of the aquatic invasive species is profiled further below.

Table C. List of Aquatic Plants Observed at Lake Nipmuc

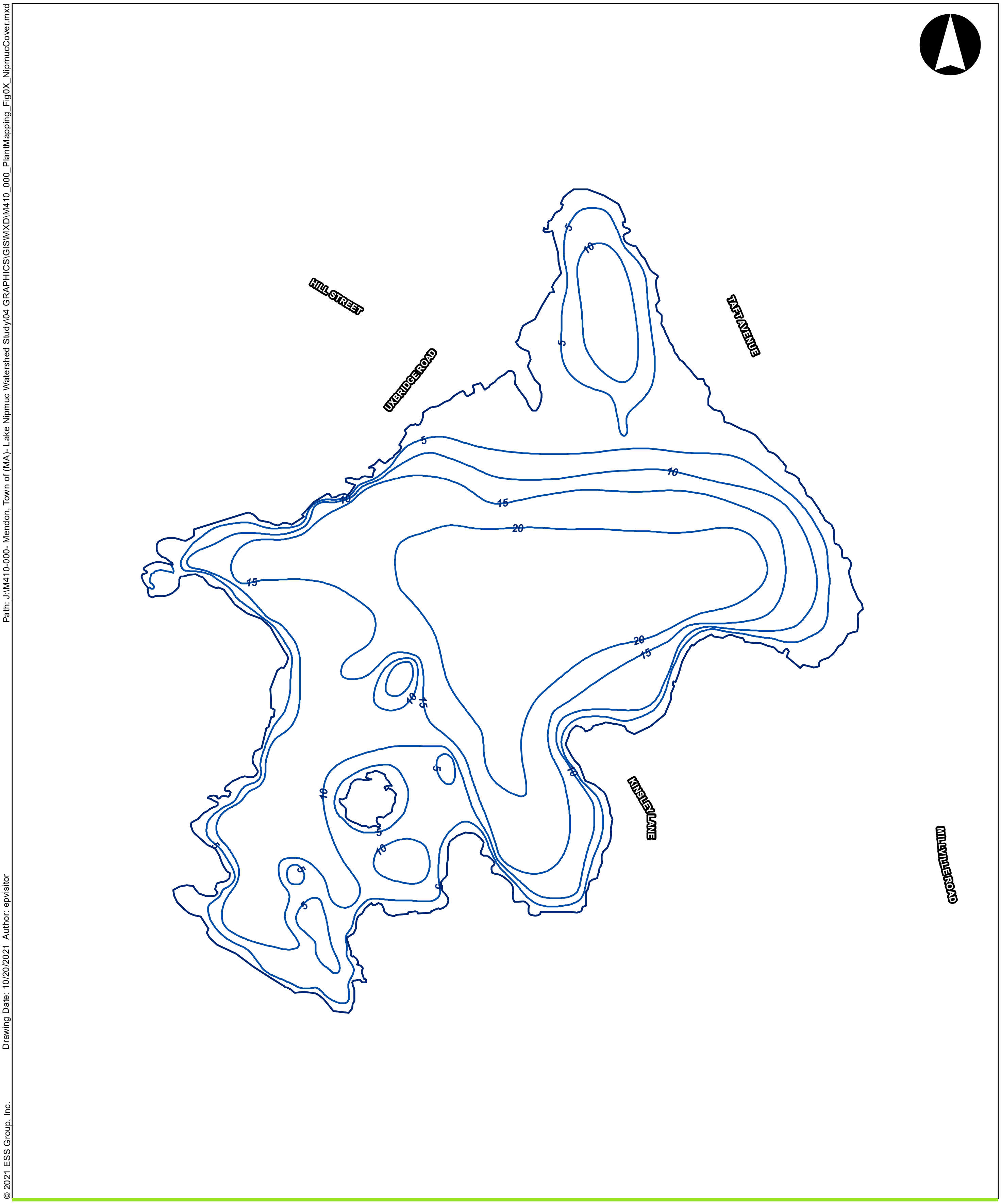
Scientific Name	Common Name	Growth Form	Status
Brasenia schreberi	Watershield	Floating-leaved	Native
Eleocharis sp.	Spikerush	Submerged / Shoreline Emergent	Native
Isoetes sp.	Quillwort	Submerged / Shoreline Emergent	Native
Myriophyllum heterophyllum	**Variable-leaf Milfoil**	**Submerged**	**Exotic**
Myriophyllum spicatum	**Eurasian Milfoil**	**Submerged**	**Exotic**
Nitella sp.	Stonewort	Submerged	Native
Nuphar lutea variegata	Yellow Water Lily	Floating-leaved	Native
Nymphaea odorata	White Water Lily	Floating-leaved	Native
Potamogeton perfoliatus	Clasping-leaf Pondweed	Submerged	Native
Potamogeton pusillus	Thinleaf Pondweed	Submerged	Native
Sagittaria sp.	Arrowhead	Submerged / Shoreline Emergent	Native
Trapa natans	**Water Chestnut**	**Floating-leaved**	**Exotic**
Utricularia macrorhiza	Common Bladderwort	Floating - submerged	Native
Utricularia purpurea	Purple Bladderwort	Floating - submerged	Native
Vallisneria americana	Water Celery	Submerged	Native

Species in **bold** are exotic

Variable-leaf Milfoil

Variable-leaf milfoil (*Myriophyllum heterophyllum*) is a submerged, perennial species native to the Midwestern United States and Canada, where it typically grows in a more restrained fashion. However, this plant can become very aggressive in softwater New England lakes and ponds, where it exhibits invasive tendencies. As with fanwort, this species spreads primarily by fragmentation. Once established, the robust plants form dense clumps of stems that may grow 10 feet or longer, often forming a monoculture and resulting in the production of substantial biomass every year. Where stems are able to reach the surface, flowering bracts may extend above the water for several weeks during the late summer.

At Lake Nipmuc, variable-leaf milfoil was found in three locations, all on the western side of the lake (Figure 4). Together, these three beds formed less than 1 acre of sparse beds.



0 260 520 Feet

Lake Nipmuc

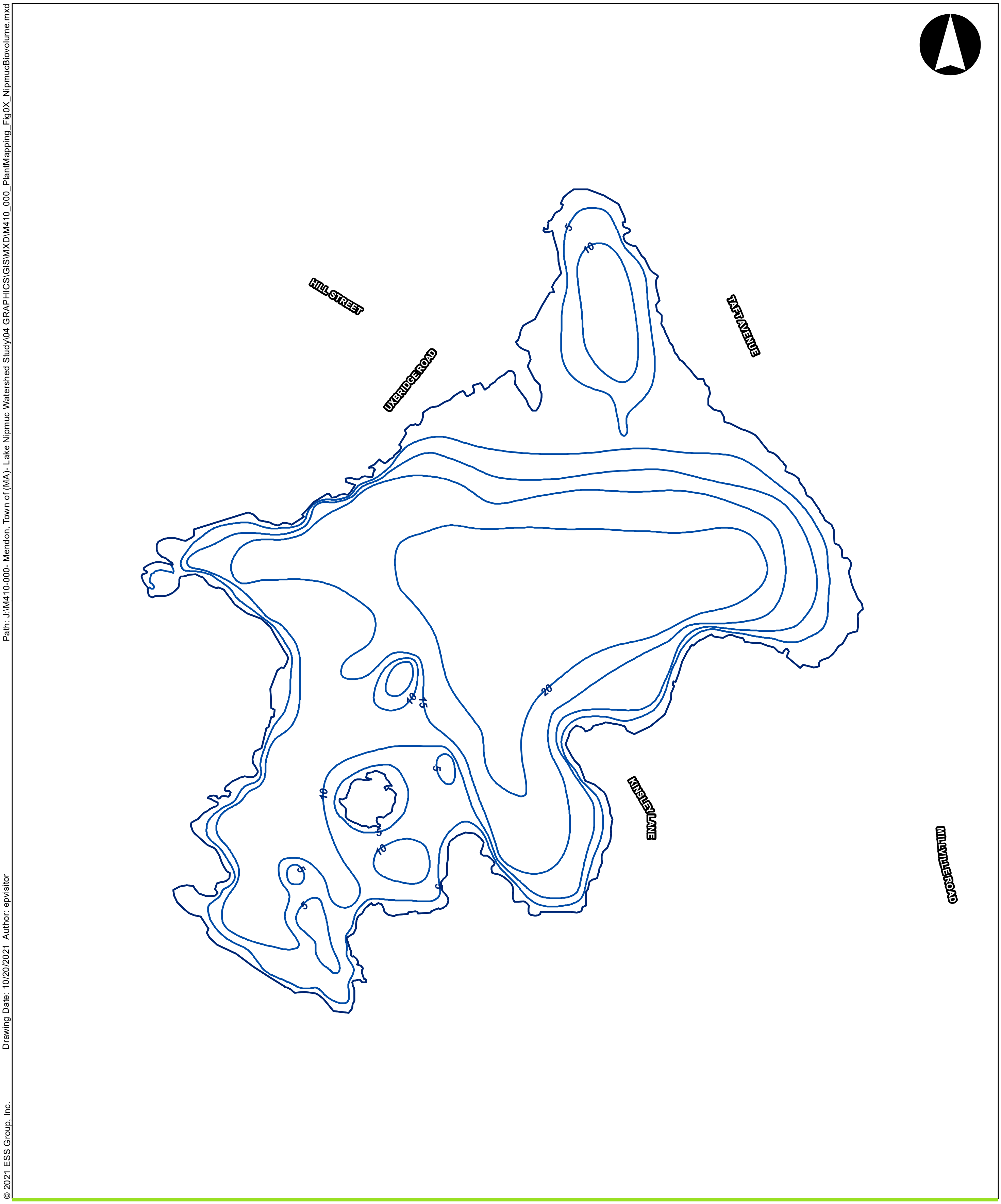
Mendon, MA

Source:
1) Esri, World Imagry, 2019
2) ESS, Field Surveys April & June 2021

- Bathymetry Depth Contour (5 Ft Interval)
- 0% (37.7 Acres)
- 1% - 25% (44.2 Acres)
- 26% - 50% (4.5 Acres)
- 51% - 75% (0.27 Acres)

Lake Nipmuc Plant Cover

Figure 2



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Lake Nipmuc
Mendon, MA

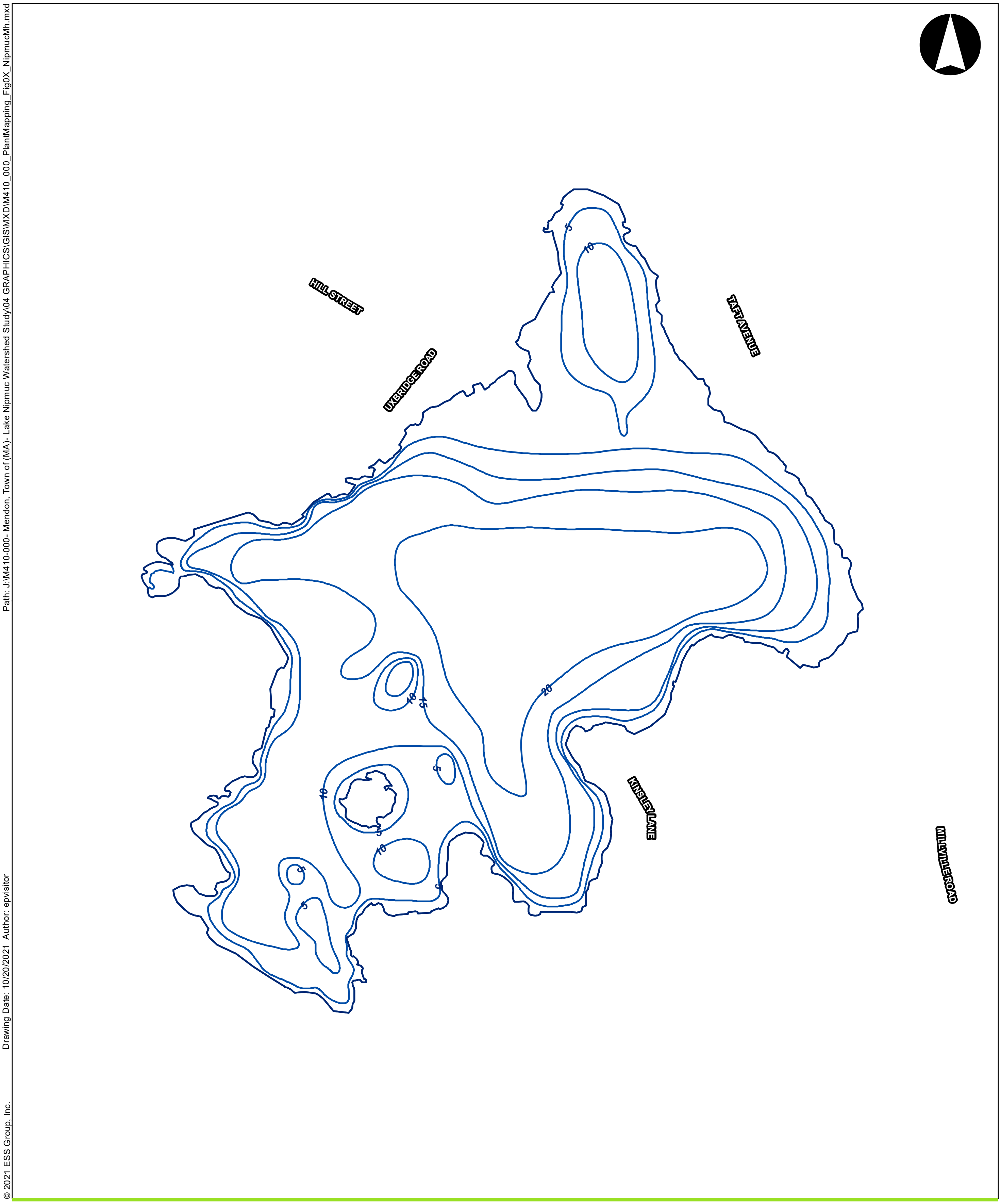
Lake Nipmuc Biovolume

0 260 520 Feet

Source:
1) Esri, World Imagry, 2019
2) ESS, Field Surveys April & June 2021

- Bathymetry Depth Contour (5 Ft Interval)
- 0% (37.7 Acres)
- 1% - 25% (48.2 Acres)
- 26% - 50% (0.8 Acres)

Figure 3



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0 260 520 Feet

Lake Nipmuc

Mendon, MA

Source:
1) Esri, World Imagry, 2019
2) ESS, Field Surveys April & June 2021

Lake Nipmuc Variable-Leaf Milfoil Cover

- Bathymetry Depth Contour (5 Ft Interval)
- 0% (86.0 Acres)
- 1% - 25% (0.65 Acres)

Figure 4

Eurasian Milfoil

Eurasian milfoil (*Myriophyllum spicatum*) is a submerged, perennial species native to Eurasia. As with variable-leaf milfoil, this species spreads primarily by fragmentation. Stems may grow 10 feet or longer, resulting in substantial biomass production every year. However, this plant tends to form patchier beds than variable-leaf milfoil.

At Lake Nipmuc, Eurasian milfoil covered less than 1 acre as a sparse bed in the far southwestern corner of the lake (Figure 5).

Water Chestnut

Water chestnut is a floating-leaved, annual species native to Eurasia and considered invasive in New England. This plant produces excessive biomass, both in the water column and in the form of the rosettes, which float at the surface. The floating rosettes shade the water column, reducing photosynthesis by submerged plants and preventing the free exchange of oxygen across the surface of the water. This can result in depletion of dissolved oxygen in the water column.

Water chestnut rosettes flower in summer with seed set shortly thereafter. The sharp and hard-coated seeds ripen from August through autumn. Once seeds drop to the sediments, they form a seed bank that may remain viable for years. Therefore, annual prevention of seed drop is critical to success in managing this species.

At Lake Nipmuc, water chestnut was found as an isolated plant near the shallow “channel” that connects the far northern sub-basin with the main central basin of the lake (Figure 6).

Eurasian milfoil (left), variable-leaf milfoil (center), and water chestnut (right) were each present in Lake Nipmuc.

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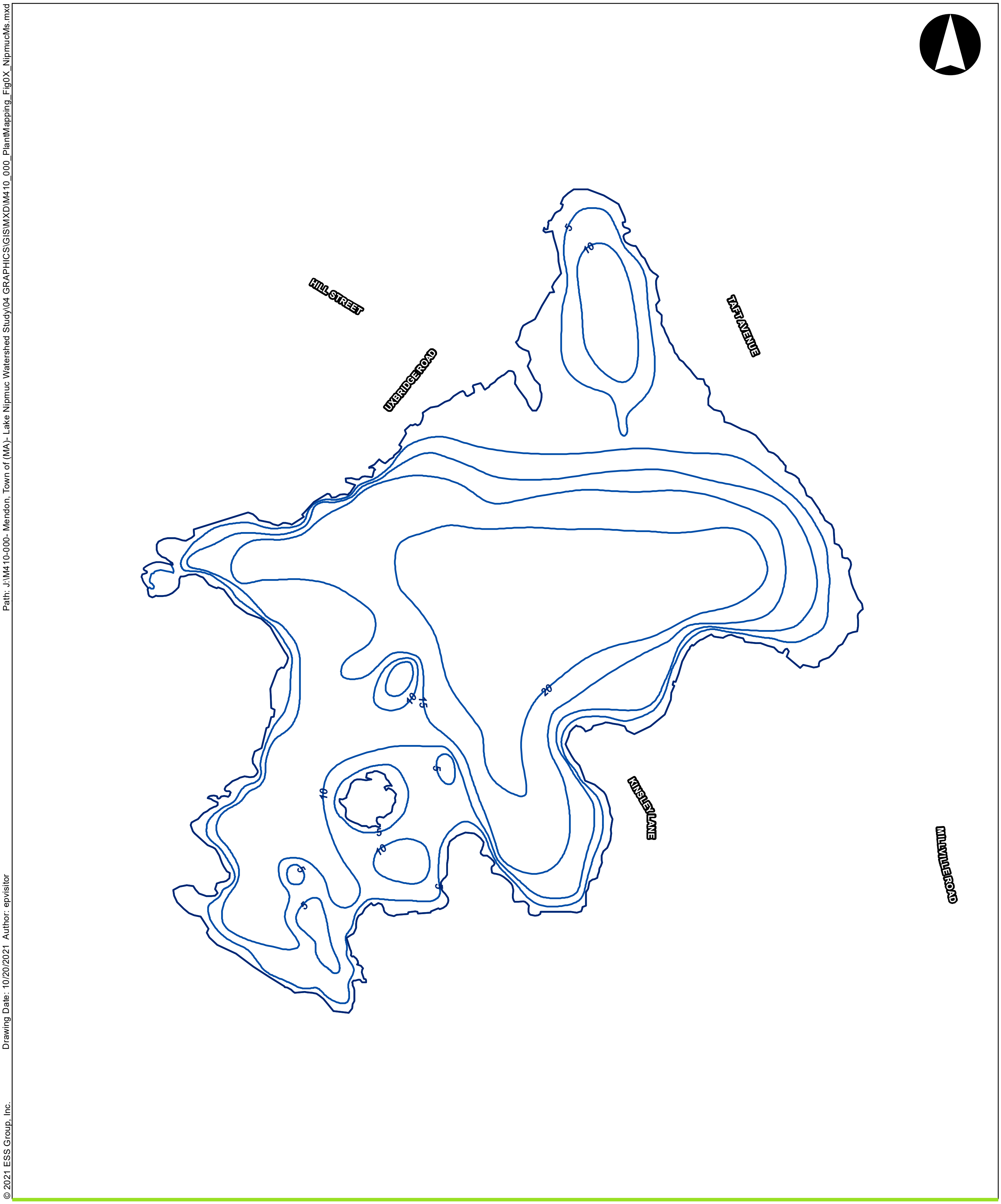

0 260 520 Feet

Lake Nipmuc
Mendon, MA

Source:
1) Esri, World Imagry, 2019
2) ESS, Field Surveys April & June 2021

Bathymetry Depth Contour (5 Ft Interval)
0% (86.5 Acres)
1% - 25% (0.22 Acres)

Lake Nipmuc Eurasian Milfoil Cover

Figure 5

Drawing Date: 10/20/2021 Author: epvisitor
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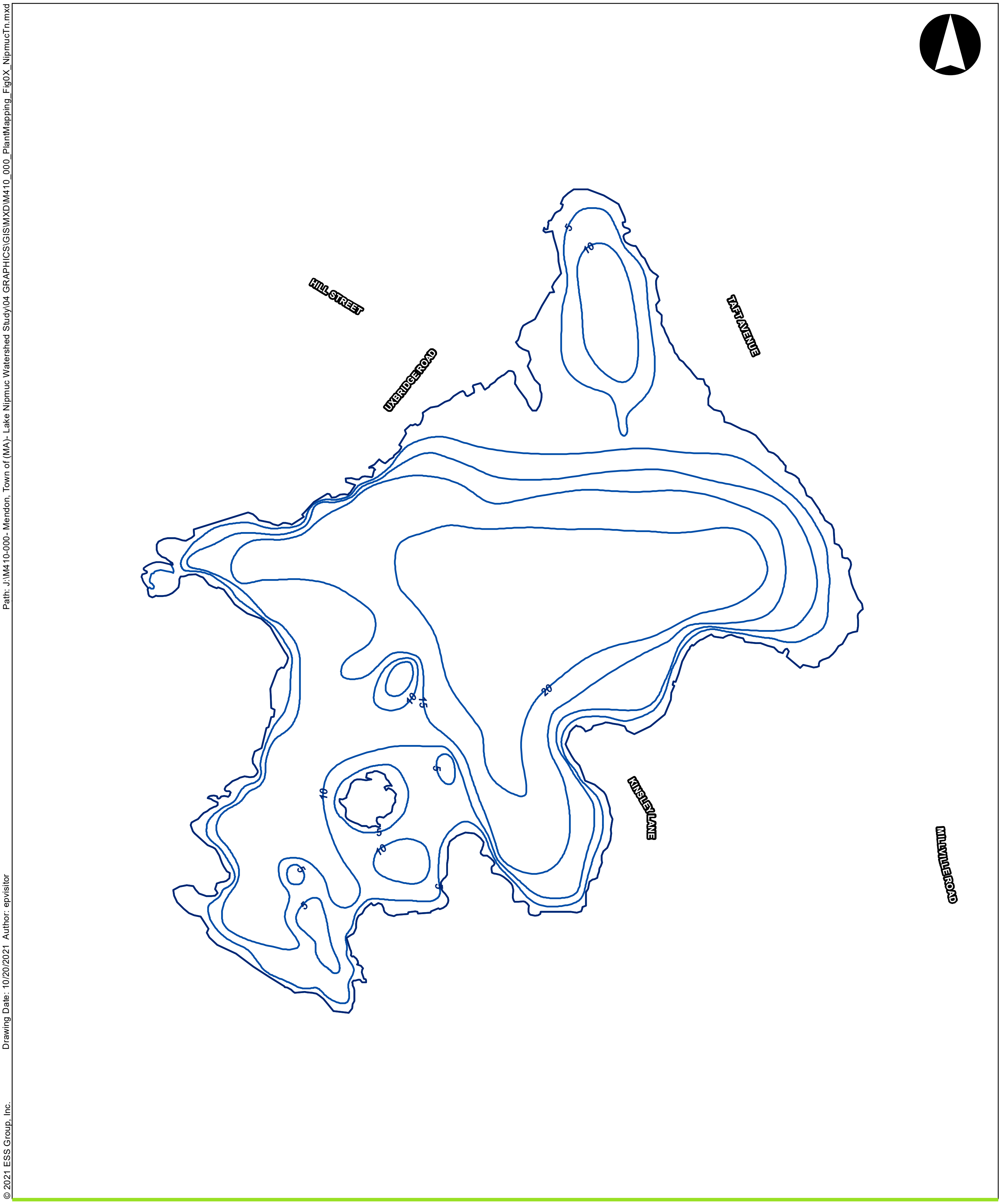


0 260 520
Feet

Lake Nipmuc
Mendon, MA

Source:
1) Esri, World Imagry, 2019
2) ESS, Field Surveys April & June 2021

Bathymetry Depth Contour (5 Ft Interval)
0% (86.6 Acres)
1% - 25% (0.1 Acres)

Lake Nipmuc Water Chestnut Cover

Figure 6

Other Biological Observations

Two of the dead fish observed along the eastern shoreline of Lake Nipmuc on June 8, 2021.

ESS observed a fish kill event at Lake Nipmuc on June 8, 2021. Fewer than 10 dead fish were found washed up along the shoreline to the north of Site 1 (Town Beach). All of the fish observed by ESS appeared to be bluegill (*Lepomis macrochirus*). Later in the day, ESS was informed that local residents had also observed at least 40 additional dead fish of multiple species in the northernmost cove. The cause of this fish kill has not been established.

Otherwise, the most frequently observed wildlife species at Lake Nipmuc were resident waterfowl. Canada Goose was the most abundant resident waterfowl species, observed in groups of up to 15 individuals on one occasion, although Mallard (*Anas platyrhynchos*) was also present. Both species were observed at or near the Site 1 (Town Beach) at least once.

Numerous other fish and wildlife species would be expected to use the lake but were not directly observed the field visits conducted for this project.

3.4 Water Quality

Water quality results for Lake Nipmuc are discussed by parameter in the following sections. However, it should be noted that the water quality results presented in this report represent a limited snapshot of water quality in the lake and a select group of parameters. Each of these parameters should be expected to vary on a daily, seasonal, and interannual basis.

Surface Water

Dissolved Oxygen

As in terrestrial ecosystems, oxygen is required to support respiration in most life associated with aquatic ecosystems, including plants, algae, fish, invertebrates, and many other life forms. Oxygen dissolves in water at a rate inversely related to temperature; solubility increases with decreasing water temperature.

Additionally, the concentration of dissolved oxygen impacts chemical processes in water. Metals, such as iron and manganese, may become more soluble in their reduced forms, which dominate under anoxic conditions. Similarly, nutrients like phosphorus may be released at a higher rate from bottom sediments when dissolved oxygen is low.

In Massachusetts, the state instantaneous dissolved oxygen standard for support of warmwater fisheries in Class B waters is 5.0 mg/L (or as naturally occurs).

At Lake Nipmuc, the observed dissolved oxygen concentrations met the warmwater standard at the surface during each of the three in-lake water quality sampilng events but did not meet the state standard at the bottom of the water column during the September sampling event (Figure 7, Table D).

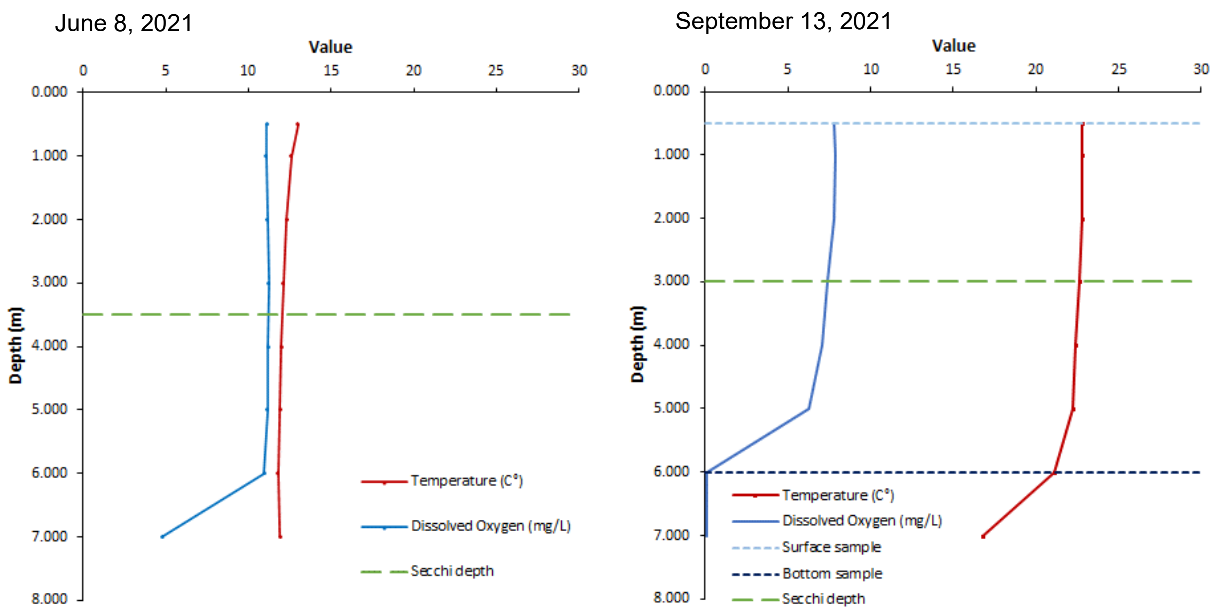


Figure 7. Temperature and Dissolved Oxygen in Lake Nipmuc

Table D. In-Lake Vertical Water Quality Profiles at Site 6 (Deep Hole)

Depth (m)	June 25				September 13										
	Temp (°C	DO (mg/L/ % sat)	SC (µS/ cm)	Secchi (m)	Temp (°C)	DO (mg/L/ % sat)	SC (µS/ cm)	Secchi (m)	pH (SU)	Turb (NTU)	Total P (mg/L)	Nitrite-N (mg/L)	Nitrate-N (mg/L)	TKN (mg/L)	E. coli (MPN/ 100mL)
0.5	13.0	11.11 107.6	399	3.5	22.8	7.79 91.9	361	3.0	7.3	1.82	0.007	<0.010	<0.02	0.44	51
1.0	12.6	11.06 106.1	398	NA	22.8	7.87 92.3	364	NA	NA	NA	NA	NA	NA	NA	NA
2.0	12.3	11.15 106.0	399	NA	22.8	7.78 91.2	364	NA	NA	NA	NA	NA	NA	NA	NA
3.0	12.1	11.24” 106.1	399	NA	22.6	7.40 89.1	364	NA	NA	NA	NA	NA	NA	NA	NA
4.0	12.0	11.21 105.6	398	NA	22.4	7.05 82.2	364	NA	NA	NA	NA	NA	NA	NA	NA
5.0	11.9	11.17 105.0	399	NA	22.2	6.26 73.4	365	NA	NA	NA	NA	NA	NA	NA	NA
6.0	11.8	10.95 103.1	399	NA	21.1	0.06 0.9	385	NA	NA	NA	NA	NA	NA	NA	NA
7.0	11.9	4.80 45.2	400	NA	16.8	0.06 0.6	407	NA	7.0	2.96	0.027	<0.010	<0.02	0.71	59

Specific Conductance

Conductivity is a measure of dissolved ions (salts) in the water. Although there are no state numerical standards for conductivity, measurements much above 100 µS/cm appear to be associated with human impact in eastern Massachusetts, except near the immediate coast or limestone outcrops. Pavement deicing is one of the most obvious sources of human-derived conductivity, although landscape practices (such as liming and fertilization), septic systems, and treated wastewater discharges, among other contributions may also serve as sources.

In-lake measurements of specific conductance at Lake Nipmuc ranged from 361 µS/cm to more than 400 µS/cm at Site 6 (Table D). Other surface water readings of specific conductance ranged from 100 µS/cm at Site 4 (Pipe) during dry weather to 480 µS/cm at Site 2 (Outfall) during wet weather (Table E). The factors driving these highly variable specific conductance readings are uncertain. However, the highest and second-highest values were both observed discharging into the northern portion of Lake Nipmuc, from Route 16 and Old Taft Road, respectively.

Table E. Surface Water Quality Results from Other Sites

Date	Sample	Flow (cfs)	Temp (°C)	Spec. Cond. (µS/cm)	Total Phosphorus (mg/L)	Nitrite + Nitrate-N (mg/L)	TKN (mg/L)	E. coli (MPN/ 100mL)	Notes
June 25 (Dry)	Site 1 – Beach (Lake)	N/A	19.5	410	0.014	<0.10	0.454	54.75	Clear, no odor
	Site 3 - Outlet	N/A	19.7	410	0.013	<0.10	0.387	13.23	Clear, no odor
	Site 4 - Pipe	0.0006	19.1	100	<0.010	0.79	0.554	<1	Clear, no odor
July 12 (Wet)	Site 1 – Beach (Runoff)	0.23	19.1	160	0.050	1.4	0.563	4,266	Clear, no odor
	Site 2 - Outfall	0.47	21.2	480	0.027	0.31	0.420	68.44	Clear, no odor
	Site 5 – Shoreline Flow	0.04	22.7	430	0.012	<0.10	0.371	14.6	Clear, no odor

pH

The pH of water indicates whether it is acidic (< 7 SU), circumneutral (~7 SU), or basic (> 7 SU). As with dissolved oxygen, pH may vary substantially over distances and over time (even a single day). For example, this parameter can rise with increased aquatic photosynthesis (such as during an algae bloom) and fall with increasing temperature. Therefore, snapshots of pH (as collected in this study) should be interpreted with caution.

In Massachusetts, the state standard in Class B waters is 6.5 SU to 8.3 SU and not more than 0.5 SU outside of the natural background range.

The surface and bottom waters of Lake Nipmuc were both well within the state standard (Table D).

Turbidity

Turbidity is a measure of light scattering by matter in the water column. Some waterbodies are naturally turbid.

There is no numerical standard for turbidity in Massachusetts Class B waters, although the narrative standard indicates that they shall be free of turbidity in concentrations that aesthetically objectionable or would impaire any use assigned to this class.

Turbidity was higher in the bottom waters of Lake Nipmuc than the surface (Table D). However, neither measurement was suggestive of excessive turbidity.

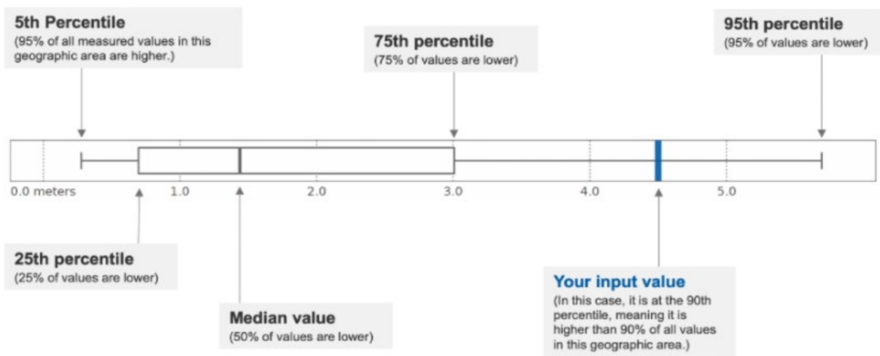
Transparency (Secchi Depth)

Water transparency is often expressed as the depth at which a Secchi disk just becomes visible. Low transparency measurements indicate poor transmission of light through the water column, although this may be due to a variety of causes including, but not limited to, natural staining, suspended sediments, algal growth, and manmade pollutants. Some waterbodies are naturally less transparent than others and low transparency does not necessarily indicate poor water quality. Higher transparencies are generally considered to be more aesthetically pleasing but also allow aquatic plants to grow at greater depths.

Transparency at Lake Nipmuc ranged between 3.0 (10 feet) and 3.5 meters (11.5 feet) (Table D). US EPA recently introduced a new lake context tool that allows users to compare their water quality values to those observed by the National Lakes Assessment program, which is conducted nationwide every five years. The last assessment was completed in 2017. Using this tool, the Secchi disk depth at Lake Nipmuc falls in the highest quartile for Massachusetts lakes, falling in the 85th percentile, although the margin of error is high. Therefore, Region 1 (which includes Massachusetts and the other New England states) may provide a more useful comparison. According to this, Lake Nipmuc is closer to the median value (the 65th percentile).

What Do These Graphics Mean?

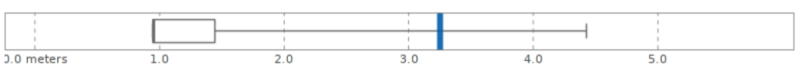
The data graphics are called **box-and-whisker plots**. The box indicates the boundaries for the middle 50% of all observations. The horizontal lines extending to the left and the right of the box are called the whiskers and indicate where the top and bottom 5% of values fall.



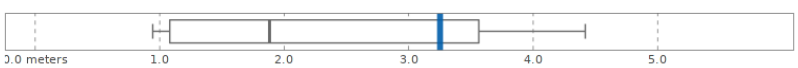
How Does Lake Nipmuc Compare to Other U.S. Lakes?

You reported that Lake Nipmuc in Massachusetts (MA) had an observed value of **3.3 meters** for Secchi Depth in 2021. The graphs below show how your lake ranks at the state, regional and national levels compared to representative data collected by the U.S. National Lakes Assessment in **2017**. For Secchi Depth, an upper percentile ranking is generally preferable.

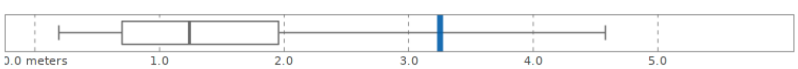
In MA, Lake Nipmuc is in the 85th percentile.*



In Region 1, Lake Nipmuc is in the 65th percentile.*



Nationally, Lake Nipmuc is in the 86th percentile.*



***Important:** These population estimates are based on a weighted analysis of lake data from the U.S. EPA's 2017 U.S. National Lakes Assessment (NLA). Secchi Depth was measured once at an open water location from May to October 2017. Sampled lakes were selected using a statistically representative approach that balances lake size with their distribution across the continental U.S. Results shown are weighted based on those factors. Percentiles are rounded to the nearest whole number. Estimated max. margin of error for MA percentile ranking, based upon limited observations: ±21.9. To learn about the NLA, please visit the EPA's website.

Nutrients

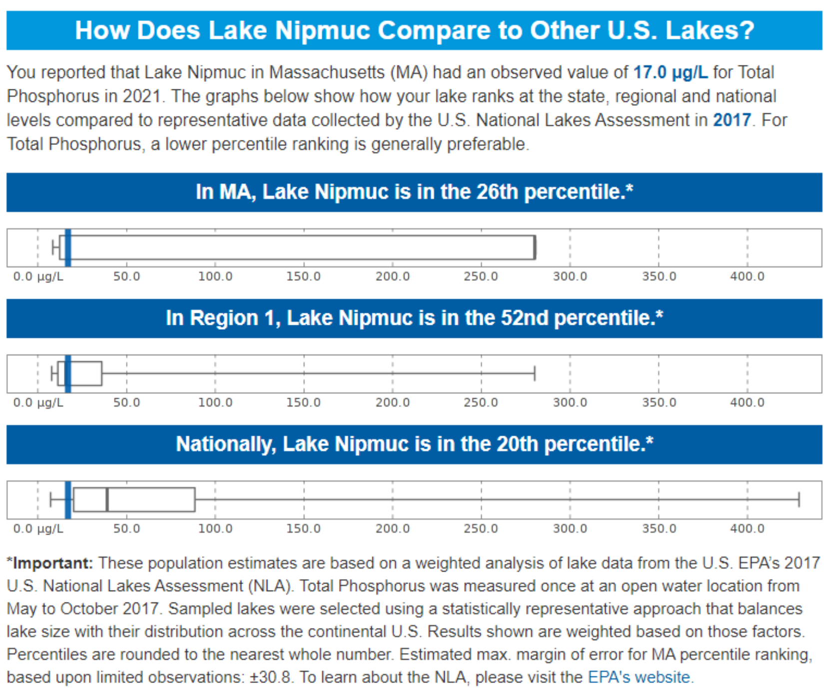
High levels of nutrients (e.g., nitrogen and phosphorus) in the water column can lead to undesirable biological consequences, such as excessive algal growth, which may also result in dominance by harmful species of cyanobacteria. Phosphorus tends to be the limiting nutrient in freshwater reservoirs while nitrogen is more likely to be limiting in brackish or salt waters, although this can vary between water bodies and over time at the same water body. Co-limitation by phosphorus and nitrogen can also occur.

Phosphorus is an essential nutrient for aquatic life but high levels of phosphorus can result in rapid growth of algae and lead to eutrophication, particularly in freshwater waterbodies. Excessive phosphorus may also encourage potentially cyanobacteria blooms to develop, which can result in taste and odor issues or production of cyanotoxins, such as microcystin.

Although there is no statewide phosphorus standard for Class B waters, concentrations in excess of 0.025 mg/L are typically considered excessive and can lead to recurring algae blooms.

The total phosphorus concentration in Lake Nipmuc was well under this value at the surface of the deep hole but exceeded it in bottom waters (Table D). The result is an average phosphorus concentration of 0.017 mg/L.

Using US EPA's lake context tool, the 2021 phosphorus concentration at Lake Nipmuc is very close to the median for Region 1 lakes, falling in the 52nd percentile.



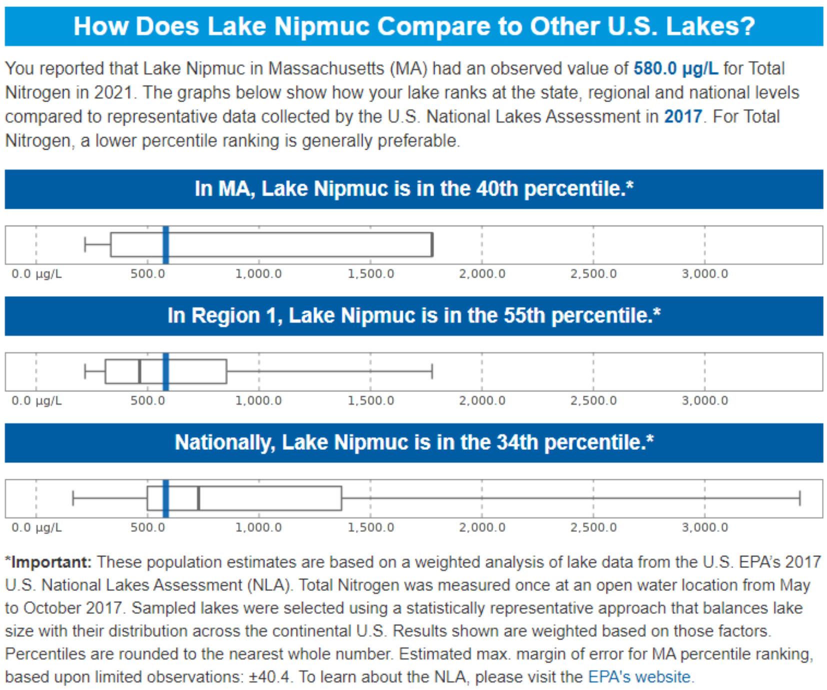
The total phosphorus concentrations at other locations was well below 0.025 mg/L during dry weather (Table E). However, phosphorus exceeded this concentration during wet weather at both Site 1 (Town Beach – Runoff) and Site 2 (Outfall), indicating that stormwater may be a source of higher phosphorus to Lake Nipmuc.

The **nitrogen** cycle is somewhat more complex than that of phosphorus. As with phosphorus, nitrogen compounds can be added to a lake via atmospheric deposition, inputs of plant matter from shoreline vegetation, and transport of nitrogen into a lake through runoff, other surface flows, or groundwater movement. However, unlike phosphorus, otherwise stable elemental nitrogen can be converted into more available forms of nitrogen and added to the lake system when it is "fixed" by cyanobacteria. Likewise, nitrogen can be removed from the lake through the process of denitrification, in which microbes convert nitrate back to inert gaseous nitrogen.

Although there is no statewide nitrogen standard for Class B waters, total nitrogen concentrations in excess of 1.0 mg/L are often indicative of excessive anthropogenic sources.

The total nitrogen concentration in Lake Nipmuc was less than 1.0 mg/L at both the surface and bottom of the deep hole (Table D). TKN was the only form of nitrogen that was detectable in laboratory samples.

Using US EPA's lake context tool, the 2021 total nitrogen concentration (TKN + nitrite-nitrogen + nitrate-nitrogen) at the deep hole of Lake Nipmuc is somewhat higher than the median for Region 1 lakes, falling in the 55th percentile.



The total nitrogen concentrations at other locations was well below 1 mg/L, except at Site 4 (Pipe) during dry weather and Site 1 (Town Beach – Runoff) during wet weather (Table E).

Bacteria

Fecal coliform bacteria, including *E. coli*, occur in the digestive tracts of humans and other animals. Although these bacteria may not always directly cause illness, they serve as indicators of fecal contamination and possible pathogens. The state standard set by the Massachusetts Department of Public Health (MDPH) is 235/100 mL for a single sample and 126/100 mL as a geometric mean.

The Town monitors the Town Beach for *E. coli* at least once a week during the summer. In 2021, the single sample standard was exceeded once (on June 21, 2021), when a value of 816.4 MPN/100 mL was obtained. From 2006 to 2016, the Town documented *E. coli* in exceedance of the MDPH standard in 2008 (once), 2009 (three times), 2010 (once), 2012 (once), 2015 (five times), and 2016 (once).

The *E. coli* in Lake Nipmuc was less than the MDPH standard at both the surface and bottom of the deep hole (Table D). Most of the *E. coli* samples collected elsewhere during dry and wet weather were also below the MDPH standard, except for Site 1 (Town Beach – Runoff), which contained *E. coli* levels of more than 4,000 MPN/100 mL on July 12, 2021.

Access path just north of Town Beach. Note flow conveyance on right side of photo. This is where runoff samples were collected for Site 1.

Groundwater

All four groundwater seepage shorelines included in this study demonstrated positive inseepage of groundwater into Lake Nipmuc. The highest rate of inseepage was observed at GW-4 in the southeastern portion of the lake and the lowest inseepage was observed at GW-2 in the northwestern corner of the lake. Inseepage at GW-4 was more than three times as high as at GW-2.

Phosphorus concentrations in shallow groundwater were highest at GW-3 and lowest at GW-2 (Table F). When combined with inseepage rate, this can be expressed as a daily load. Groundwater phosphorus loading was approximately 27 times higher at GW-3 along the southern shoreline of the lake as it was at GW-2.

Dissolved inorganic nitrogen (DIN) concentration, which is this case consisted primarily of ammonia nitrogen, demonstrated a similar pattern as phosphorus, although the highest concentration was observed at GW-4 in the far southeastern portion of the lake (Table F). When expressed as a daily load, DIN loading was more than eight times higher at GW-4 than at GW-2.

Due to the very low nitrate-nitrogen concentrations in groundwater at all shoreline sampling locations (not detectable at 0.02 mg/L), the laboratory could not extract enough nitrate-nitrogen to run the stable isotope analysis despite the submittal of a 1-L sample volume.

Table F. Shallow Groundwater Quality at Lake Nipmuc

Sample Shoreline	Phosphorus		Ammonia as N		Nitrate as N	
	Concentration mg/L	Daily Load mg/m^2/day	Concentration mg/L	Daily Load mg/m^2/day	Concentration mg/L	Daily Load mg/m^2/day
GW-1	0.010	0.020	0.63	1.29	<0.02	<0.04
GW-2	0.008	0.012	0.44	0.66	<0.02	<0.03
GW-3	0.078	0.325	1.04	4.34	<0.02	<0.08
GW-4	0.055	0.263	1.16	5.55	<0.02	<0.10

Septic systems that function correctly should have a minimal phosphorus signature because the fraction of phosphorus leached into the ground readily adsorbs onto particles in the soil matrix, rather than migrating toward the lake. Failing or poorly sited septic systems may result in discharge of phosphorus-rich wastewater into nearby water bodies. Additionally, septic systems that have been in operation for many years may load phosphorus to nearby water bodies at a higher rate, due to the saturation of binding sites for phosphorus in the soil over time.

DIN is typically much more mobile through soil than phosphorus and may generate a plume that reaches the lake quickly. Even septic systems that are regularly pumped and functioning properly typically remove less than half of the nitrogen. Therefore, DIN concentrations in groundwater can be substantially higher where septic systems are prevalent.

ESS did not observe any visible signs of potential direct septic sources, aside from the dry weather flow at Site 4 (Pipe) and Site 5 (Shoreline Flow). Although prior testing by the Blackstone River Coalition on behalf of the Lake Nipmuc Association suggests that Site 5 may yield high concentrations of phosphorus, nitrogen, and bacteria, ESS's results from direct testing of these two potential sources were insufficient to support characterization as contaminated by septic discharges. However, the seepage survey would appear to suggest the potential for greater septic system-related loading of nutrients to Lake Nipmuc along the southeastern and southern shorelines (i.e., Taft Avenue and Kinsley Lane neighborhoods). Although insufficient maintenance of tight tanks or septic systems could provide one explanation, groundwater flow patterns and/or greater intensity of use may also account for the observed differences.

3.5 Diagnostic Summary

The following key diagnostic results should be considered in assessing management issues and developing the appropriate management approaches to address them:

- Lake Nipmuc is a moderately shallow lake with some thermal stratification during the warm season. This allows for deeper waters of the lake to become isolated for periods of time, which may result in significantly different water quality conditions at the surface and bottom of the lake.
- The northernmost cove of Lake Nipmuc may experience limited exchange with the rest of the lake, especially during droughts (low water). This may allow for significantly different water quality conditions to develop in this cove when compared to the larger lake. At times, this could result in the development of local management issues, such as algae blooms, low dissolved oxygen (hypoxia), and fish kills. Additionally, the protected nature of the cove could provide shelter for the rapid establishment of aquatic invasive plants.
- Three species of aquatic invasive plants were documented in Lake Nipmuc but did not appear to be widespread or dense at the time of the survey. Of the three species, water chestnut would pose the most significant threat to water quality and aquatic habitat were it to become established, due to its ability to form a dense canopy above the surface of the water.
- Although development of hydrologic and nutrient budgets was beyond the scope of this study, it appears that wet weather (i.e., stormwater) sources of pollutants account for greater loading into Lake Nipmuc than groundwater sources. Additionally, based on the observation of deepwater anoxia and higher phosphorus in bottom waters, internal loading (recycling) of phosphorus may also account for a substantial portion of loading to Lake Nipmuc, especially during late summer or early autumn. Therefore, these sources appear to warrant additional investigation and action to address.

- Groundwater (septic) and waterfowl are likely to be secondary contributors of pollutants to Lake Nipmuc, in terms of total load contributed. However, these sources may still be very important, especially if they impact the lake at more sensitive times of the year (i.e., summer to early autumn) or focus the impact on sensitive locations, like the Town Beach. Additionally, prior testing of *E. coli*, orthophosphate, and nitrate by the Blackstone River Coalition on behalf of the Lake Nipmuc Association suggests that water quality conditions in the drainage outflow near Old Taft Ave (identified as "Yacht Club") have degraded since 2018 (based on unpublished results for 2018, 2019, and 2020 provided by the Lake Nipmuc Association).

- Swimmer's itch (cercarial dermatitis) was also suspected as a nuisance issue due to -reported cases of skin rashes reported to the Town by swimmers in 2021.

4.0 MANAGEMENT ISSUES, OPTIONS, AND NEXT STEPS

4.1 Management Issues

As a Great Pond with established public access and a municipal swimming beach, Lake Nipmuc is a valuable community resource. The lake also provides recreational opportunity and aesthetic value to abutting residents and businesses. Additionally, Lake Nipmuc constitutes the largest area of contiguous aquatic habitat for fish and wildlife in Mendon. Therefore, Lake Nipmuc serves a unique role in Town. To preserve this, the following existing or nascent management issues should be addressed:

- Bacteria – impact to primary contact recreation, including swimming at Town Beach

- Nutrients (phosphorus and nitrogen) – loading from watershed sources and potential internal source

- Algae – currently not documented to be a problem but could become one if nutrient loading is left unchecked

- Exotic aquatic vegetation – each of the exotic species present may become a severe nuisance if left unchecked

- Swimmer's itch (cercarial dermatitis) – impact to primary contact recreation, including swimming at Town Beach

4.2 Management Options

The most relevant management options for addressing the management issues at Lake Nipmuc are presented in Table G.

Table G. Issues Addressed by Most Relevant Management Options at Lake Nipmuc

Approach	Issue(s) Addressed				
	Algae	Bacteria	Nutrients	Plants	Other
In-lake Options					
Aeration/Circulation	✓	?	?		✓
Algaecides	✓				

Approach	Issue(s) Addressed				
	Algae	Bacteria	Nutrients	Plants	Other
Benthic Barriers				✓	?
Harvesting (Hand/Diver)			?	✓	?
Herbicides				✓	?
Nutrient Inactivation	✓		✓		
Resident Waterfowl Controls		✓	✓		✓
Watershed Options					
Septic System Improvements		✓	✓		
Stormwater Improvements		✓	✓		✓
Other Options					
Monitoring					✓
Public Education and Outreach	✓	✓	✓	✓	✓

In addition to these options, a number of other management options were considered but are not currently likely to be useful or feasible at Lake Nipmuc. These include but are not limited to the following:

- Barley straw
- Bioaugmentation
- Biomanipulation
- Dilution or Flushing
- Drawdown
- Dredging
- Herbivores
- Hydroraking
- Mechanical harvesting
- Plant competition
- Sonication

A brief description of each of the potentially relevant management options is presented in the following section.

In-Lake Options

Aeration/Circulation

Aeration or circulation is used to treat problems with excessive algal growth and low dissolved oxygen concentrations, typically in deep waters or stagnant coves. Air diffusers, aerating fountains, and water pumps are typical types of equipment that may be installed to increase aeration or circulation in a lake. The cost of purchasing, installing, and maintaining lake circulation equipment becomes substantial as lake size increases. Likewise, the effectiveness of the equipment tends to decline with lake size as it is difficult to achieve sufficient circulation in large bodies of water.

Therefore, this approach could potentially be of use on a small scale in the northernmost cove of Lake Nipmuc, which is somewhat removed from the primary flow path and free exchange with the main basin of the lake. In this cove, a well-designed and maintained aeration or circulation system could improve dissolved oxygen levels for aquatic life and help address excessive algal growth, should it occur.

Algaecides

Algaecides are analogous to herbicides in many ways but primarily target algae and cyanobacteria. Application of algaecides results in almost immediate control of a broad spectrum of planktonic and filamentous algae. A variety of different algaecide formulations are available for use, including copper sulfate and chelated copper-based formulations (e.g., Captain and K-Tea), which will generally control most nuisance green algae and cyanobacteria species. Peroxide-based formulations (e.g., PAK 27) are also available for control of nuisance algae, although these tend to be more expensive. Water use restrictions associated with most algaecides are minimal and temporary. Some labels do not carry any restrictions.

Algaecides may be useful for short-term control of algal blooms or patches of filamentous algae on an as-needed basis. Although effective, algaecides treat only the symptom (i.e., excessive algae) and do not address the cause of algae blooms (i.e., excessive nutrients). Therefore, long-term improvements should not be anticipated from the use of algaecides alone.

Benthic Barriers

Benthic barriers are negatively buoyant materials, usually in sheet form, which can be applied on top of plant beds to limit light, physically smother, and allow unfavorable natural chemical reactions to interfere with further development of plants. Benthic barriers are best used for providing control of nuisance aquatic plant growth on a localized basis. They are most likely to be of use near shore and in the vicinity of shoreline structures where they can most easily be installed and maintained.

Plant topgrowth under the barrier will usually die back after about a month of deployment, although it may take longer for root crowns of perennial species to succumb. Barriers of sufficient tensile strength can be moved to a new location once control has been achieved, if desired. However, the continued presence of barriers will restrict recolonization of the area, especially if the barrier is maintained on a regular basis to prevent accumulation of sediments and billowing by trapped gases.

Benthic barriers are likely to generate both direct and indirect impacts to non-target species where they are deployed. This is due to the fact that benthic barriers are non-selective, which means all plants in the treatment area are killed, including desirable native plants. By smothering bottom sediments, barriers can also impact the invertebrate community within the treatment area, which may locally reduce food sources for fish. Another drawback of benthic barriers is that recolonization from adjacent plant beds can occur quickly once the barrier has been removed. However, with experience, the barrier deployment and removal timing can be optimized to encourage recolonization by annual native species while keeping nuisance perennial species at bay.

Benthic barriers may be most effective near public access locations (e.g., Town Beach) to smother plant beds should they encroach on the swimming beach.

Harvesting

The simplest form of harvesting is hand pulling of selected plants. Depending on the depth of the water at the targeted site and the type of plant being controlled, hand harvesting may involve wading, snorkeling, or SCUBA diving. Pulled plants and fragments are placed in a mesh bag or container that allows for transport and disposal of the vegetation. Hand harvesting of submerged perennial vegetation (e.g., milfoils) aims to remove entire plants, including the roots, thereby preventing re-growth in subsequent seasons. Usually, divers are required to do that effectively. Hand harvesting of water chestnut is much simpler because the bulk of the biomass is produced at the water's surface. Therefore, water chestnut can be effectively pulled from a boat, kayak, or canoe.

Hand harvesting is an excellent approach for control of pioneer infestations, when bed extent and density are limited. It is also the ideal control measure for small infestations of water chestnut, when implemented between June and early August (i.e., before the water chestnut seeds ripen and drop). Although divers are typically required, most pioneer infestations can be effectively contained or even eradicated with a day or two of harvesting. Hand harvesting in these cases should proceed as soon as possible to prevent further spread of the plants. This should be followed by detailed surveys of the area to find and remove any plants that may have been missed or incompletely removed by the dive team.

As with any physical plant removal program, implementation of hand harvesting operations should include identification of temporary stockpiling and permanent disposal areas as well as fragment release control methods prior to initiation of each project phase.

Herbicides

The primary advantage of herbicides is that they can be used to efficiently address management issues over large areas within a relatively small timeframe and with little or no physical disturbance. Label restrictions are typically limited to irrigation with few or no restrictions on use for primary recreation, boating, fishing, or drinking. Therefore, direct impacts to non-target species or practical use of the lake are usually minimal. Rather, indirect impacts (e.g., changes in aquatic vegetative cover or temporary increase in oxygen demand as plant dieback occurs) are often the primary concern. However, these impacts can be managed through appropriate selection and application of herbicides.

Although a number of herbicides are available to control the aquatic invasive milfoils found at Lake Nipmuc, florpyrauxifen-benzyl (trade name ProcellaCOR) is likely to be the most appropriate. ProcellaCOR is a reduced risk systemic herbicide that acts as an auxin mimic. Auxin is a key plant hormone that regulates growth processes; herbicides that mimic auxin are able to control target species by disrupting these processes. In certain dicots, auxin mimics can be very effectively translocated throughout the plant, allowing the growth disruption to impact the overall plant and eventually resulting in death.

The primary factor favoring ProcellaCOR is that it is selective for control of exotic milfoils at low concentrations without impacting most native aquatic plant species. It also requires much less contact time than most systemic herbicides. This means that it can be applied at very low doses and is unlikely to require costly booster treatments. These factors make ProcellaCOR both cost-effective and protective of non-target plants when treating exotic milfoils.

Nutrient Inactivation

This approach may be adjusted to target long-term binding of phosphorus in the sediments, stripping of water column phosphorus and algae, or maintenance of water quality using alum (aluminum sulfate) and/or other nutrient inactivation chemicals.

Although other nutrient inactivation agents are available, alum and sodium aluminate are the two most commonly used. These have a long track record of successful use and are generally more economical to apply than other materials.

Sediment nutrient inactivation programs are commonly implemented in deep lakes where sediment phosphorus release is a substantial component of the total phosphorus load and flushing rates are low. Such a program would be an ambitious undertaking and require thoughtful logistical planning to allow for delivery and storage of materials as well as access for the treatment vessel, which may be of substantial size. Furthermore, additional study would be needed to properly design the treatment for maximum longevity and minimum impact to aquatic life. However, a well-executed sediment nutrient inactivation program can provide a decade or more of water quality improvement in deep lakes with high internal phosphorus loading rates.

Low dose alum treatments are similar to sediment nutrient inactivation but involve much smaller applications that are primarily targeted at stripping phosphorus and particulates (including algae and suspended sediments) from the water column. Unlike a copper algaecide treatment, alum addresses the proximal cause of nuisance algal blooms, which is the excess availability of nutrients. Therefore, it provides benefits above and beyond those of algaecide treatments. Low dose treatments require some planning but are substantially easier to implement than sediment nutrient inactivation.

Resident Waterfowl Controls

Waterfowl serve as the primary host for the parasitic organisms that cause swimmer's itch (also known as cercarial dermatitis). Migratory species of waterfowl may carry the parasite but they tend to spend fewer days in a given water body and, in eastern Massachusetts, tend to be present outside of the summer season. However, resident waterfowl (primarily Canada Goose) are present year-round and tend to spend the most time in or near the water during the late spring and summer, when they are actively nesting and molting. Therefore, reducing the resident waterfowl population may, in turn, help to reduce the source of the schistosomes that cause swimmer's itch. Resident waterfowl control would also reduce undesirable inputs of nutrients and bacteria to Lake Nipmuc to some degree.

Management of the resident Canada Goose population is most likely to be accomplished if multiple active and passive control options are implemented as part of a comprehensive effort. Active control options include egg addling (to prevent recruitment of new geese) and harassment of adult geese (to discourage geese from remaining in the area). Passive control options include behavior changes, such as raising the cutting height on lawnmowers and/or reducing mowing frequency. Geese find taller grass to be less palatable and gravitate to closely cropped lawn areas instead. Chemical repellents, decoys, and barriers (e.g., fencing) are other passive measures that can sometimes succeed, at least for short periods of time.

Watershed Options

Septic System Improvements and Upgrades

Septic systems provide on-site treatment of sewage for homes and businesses that are not connected to a sanitary sewer. Septic failures may result in ponded or flowing wastewater at the ground surface or into surface waters, which presents a potential public health issue. Additionally, failed, inappropriately sited, or inadequately designed systems may also contribute nutrients to surface waters, which can fuel excessive algal growth.

Although it was beyond the scope of this study to determine, the upgrade or repair of onsite septic systems may be a less costly and reasonably effective alternative to sewering entire neighborhoods around Lake Nipmuc.

Septic system repairs, improvements, and more frequent maintenance could help reduce the nutrient load associated with these systems in the watershed. Where setbacks or site conditions are insufficient to ensure the proper functioning of traditional septic systems, alternative innovative designs may be appropriate. A wide variety of approaches and designs exist. Some examples include aerobic treatment units, recirculating sand filters, and composting toilets. However, one drawback of non-traditional septic systems is that these systems do not have as long a record of performance and the guidelines for proper operation may not be as well-established, especially for those that rely on proprietary technologies. This may result in confusion on the part of residents and/or regulators with regard to ensuring proper operation and maintenance of the systems.

Stormwater Improvements

External nutrient loading can be mitigated to some degree through watershed controls, especially when enforced and implemented as a condition for new or re-development. However, once watershed land is developed, watershed controls become increasingly difficult to implement and typically require large-scale disconnection of impervious surfaces or retrofits to achieve even small reductions in nutrient, sediment, or bacteria loading. Retrofits can be effective but typically cost many times more to construct and maintain than other means of addressing pollutants.

Other watershed measures, including agricultural and forestry best management practices (BMPs), can also reduce the amount of nutrient loading from non-urbanized land. Because the Town only controls a small portion of the land in the watershed, work toward BMP implementation is most likely to take the form of coordination with state agencies, non-governmental organizations, and private individuals.

Development and re-development within the watershed should incorporate low impact development (LID) stormwater techniques or green infrastructure in line with the latest version of the Massachusetts Stormwater Handbook and applicable regulations to prevent further deterioration of influent water quality. Small municipal separate storm sewer system (MS4) operators in Massachusetts are required to adopt or update municipal stormwater by-laws to comply with the Small MS4 General Permit. Encouraging stricter municipal stormwater regulations and LID standards can also help control watershed pollutant sources.

<u>**Other Options**</u>

Monitoring

Implementation of a long-term monitoring program is critical for understanding and tracking trends in managed lakes, as well as preventing or containing new issues as they arise.

At a minimum, monitoring should include assessment of water quality parameters. Water quality data are of limited value if not collected relatively frequently. Therefore, in addition to the required beach monitoring, the Town may wish to consider a monthly monitoring program of ambient in-lake water quality, especially during the growing season. Phosphorus, nitrogen, *E. coli*, dissolved oxygen, temperature, and transparency [Secchi depth] would all be key parameters to target. A number of reliable water quality monitoring sensors and data loggers are now on the market and could provide continuous data collection with minimal labor required.

Additionally, vegetation mapping efforts should be completed during the peak of aquatic plant growth, at least once a year. This mapping should include aquatic plant species distribution, cover, and biovolume. Vegetation mapping twice a year (i.e., pre- and post-implementation) is recommended when management actions are implemented.

A large portion of the data could potentially be collected by trained volunteers for cost-effectiveness. However, to make the most of the data collected by the monitoring program and provide interpretation of the trends, professional review and evaluation is recommended

Public Education and Outreach

Public education and outreach will raise awareness of issues at Lake Nipmuc and encourage public involvement in its protection and management as a community resource, particularly with regard to prevention of future problems as well as extension of benefits from other management actions that may be implemented. In particular, development of a public education program about good housekeeping measures (proper maintenance) could help prevent septic system failure and degradation of water quality.

Education and outreach may take many forms. These may include content on hosted on the Town website, social media postings, targeted mailings, incorporation into school programs, community events, installation of informational signs or kiosks at public access locations, or other approaches.

Organized public participation programs may provide an enhanced opportunity for members of the public to take a more active role in supporting Lake Nipmuc. Examples may include labeling of storm drains, replanting of native plants on public lands or rights-of-way, or development of a citizen water quality monitoring program. Additionally, the Massachusetts Weed Watchers program, sponsored by the Department of Conservation and Recreation Lakes and Ponds Program, provides training and technical assistance to public groups interested in monitoring their lakes for exotic species of aquatic plants.

4.3 Next Steps

- Prioritize goals and objectives for Lake Nipmuc.
  - This action should be undertaken by the Town and stakeholders to refine and prioritize their goals and objectives for Lake Nipmuc, using the information presented in this report.
- Develop long-term lake management plan for Lake Nipmuc.
  - Identifies primary management issues of concern.
  - Defines management goals.
  - Fills key data gaps.
  - Identifies the preferred management options and at least the general locations where they will be implemented. Describes how each preferred option addresses the key management issues and achieves the management goals for the lake.
  - Sequences the design, permitting, and implementation of preferred management options and annual costs, typically over a five-year period.
- Pursue funding, permit, and implement the lake management plan for Lake Nipmuc.
  - Funding is often secured in a stepwise nature, especially if public grants are the primary funding source. Local fundraising efforts can expedite the funding progress significantly if community buy-in is strong.
  - Almost any management action is likely to require a permit and some will require more than one permit, potentially from multiple agencies at the local, state, and/or federal level.
  - The permitting cost will be dependent on the management actions selected. Some actions can be permitted without significant additional study or cost while others may require engineering design and/or additional environmental testing.
  - Most management actions are cyclical over time and/or regular maintenance to remain effective.
- Monitor, evaluate progress, and adjust or optimize the lake management program over time.

5.0 POTENTIAL FUNDING OPTIONS

Although a number of funding opportunities exist to address watershed water quality and stream continuity issues, fewer funding opportunities are targeted specifically to in-lake management work. Often, these kinds of projects are funded through locally generated funding sources, such as the Community Preservation Act (CPA), which can also leverage state monies. The Mendon Community Preservation Committee (CPC) is responsible for funding these projects in the Town of Mendon. The development of lake management plans and collection of supporting data are usually eligible under this program, as long as the lake is publicly accessible (which Lake Nipmuc is). Costs associated with design and permitting of lake or watershed improvement projects are also typically eligible. Additionally, project implementation may also be eligible as long as the project is not considered to be a maintenance activity. Even if CPC funds are not sufficient to fund an entire project, they can often be used as match to help leverage funding from state or federal grant programs.

The state Municipal Vulnerability Preparedness program may also be a source of funding through an MVP Action Grant. This grant program is relatively new and is focused on adaptation to climate change impacts. However, ESS is aware of other organizations that have received project funds for lake and pond projects.

To be eligible, a project must specifically address how it will prepare the community and its environmental resources for resiliency in the face of climate change impacts. Given Lake Nipmuc's status as key recreational resource with a public swimming beach, this program could potentially be a source of funding.

Another newer program is the Massachusetts Water Quality Monitoring grant, administered through MassDEP. This grant can be used to purchase water quality monitoring equipment and supplies or otherwise expand community capacity for water quality monitoring. Although the grant is targeted to non-governmental organizations, municipalities can also benefit from the monitoring data generated under the grant.

Other state and federal funding opportunities (including loan programs) that may be relevant to Lake Nipmuc frequently arise through US EPA and/or the Southeast New England Program, the New England Interstate Water Pollution Control Commission (NEIWPCC), and various state grant programs (including the Massachusetts Environmental Trust). However, the funding, focus, and requirements of these programs may vary from year-to-year. Therefore, it may be worthwhile to evaluate these programs for potential project funding on an annual basis.

The state-managed Section 604(b) and Section 319 grant programs are funded annually and target watershed water quality. Both of these grant programs are highly competitive and cannot be used to fund activities that are required for compliance with the Town's small municipal separate storm sewer system (MS4) permit.

The Section 604(b) grant program has no match requirement and may be used for watershed assessment programs, conceptual design of stormwater BMPs, or other types of projects associated with identification of and initial response to pollutant sources. Section 604(b) grant awards typically range from $30,000 to $50,000 but can be somewhat higher or lower.

The Section 319 grant program typically requires a 40% non-federal match but can be used to fund permitting, final design, construction, or other implementation of previously identified strategies or BMPs. However, project eligibility may be restricted to locations that are not currently covered through an MS4 general permit. Typical award values range from $100,000 to $300,000 but awards outside of this range are occasionally made, particularly on the higher end.