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Revised January 12, 2023

Lake Management Study Committee
Town of Sharon
90 South Main Street
Sharon, Massachusetts 02067

Re: ***Lake Massapoag Water Quality Assessment and Aquatic Plant Mapping***
Sharon, Massachusetts
TRC Project No. 481848.0000.0000

Dear Lake Management Study Committee,

TRC Environmental Corporation (TRC), provides the Town of Sharon Lake Management Study Committee (the Town) with this summary report of the 2022 water quality assessment and aquatic plant mapping program at Lake Massapoag.

Approach

TRC completed field visits to Lake Massapoag on June 2, July 26, and October 3, 2022. During each of these visits, TRC sampled and directly measured water quality conditions in the lake. Additionally, TRC collected sediment samples and mapped aquatic plants in the lake during the October 3 visit. A description of the approach used for each of these activities is presented in the following sections.

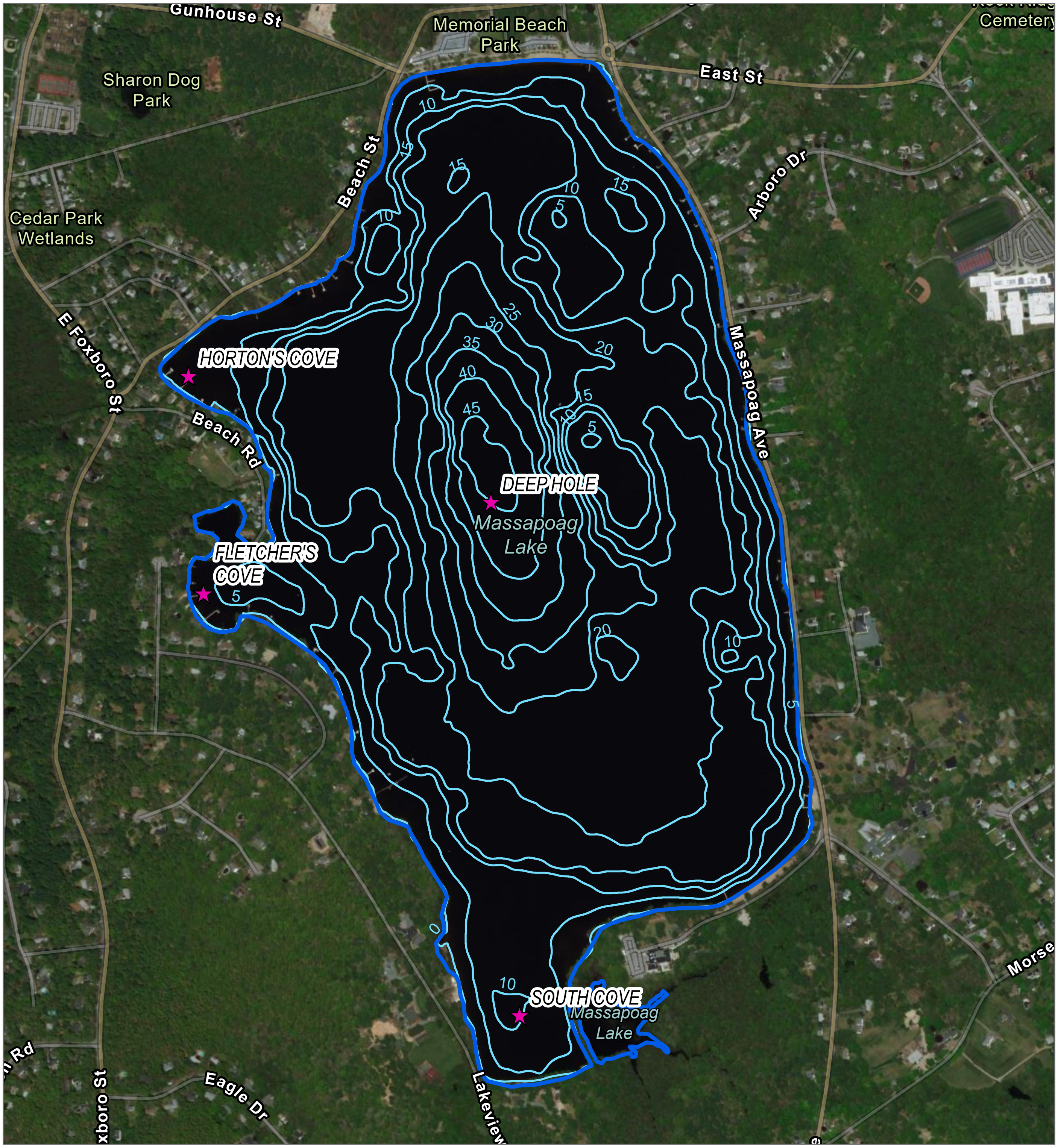

Total dissolved phosphorus samples were field-filtered to extend the laboratory holding time.

Water Quality Monitoring

TRC completed three rounds of water quality monitoring at Lake Massapoag. Samples were collected at four locations during the June event and five locations during the July and October events. Sampling locations included the surface and bottom of the lake at the deepest spot (deep hole) as well as two to three other surface monitoring locations in selected coves on the western and southern periphery of the lake (Figure 1). This approach was designed to capture a representative spectrum of water quality conditions both laterally and vertically within the lake over the course of the growing season.

Water quality was assessed through direct measurement, as well as the collection of samples for laboratory analysis. Field measurements included the following:

- Water transparency (Secchi disk depth)
- Water temperature
- Dissolved oxygen (concentration and percent saturation)
- Specific conductance
- pH
- Turbidity



★ WATER QUALITY SAMPLE LOCATIONS

BATHYMETRY CONTOURS (FEET)

BASE MAP: ESRI, WORLD IMAGERY, 2022
DATA SOURCES:
TRC, GPS LOCATIONS, 2022
MASSGIS, INLAND WATER BATHYMETRY, 2019

N

0 500 1,000 FEET

1:11,500 1" = 958'

PROJECT: **LAKE ASSESSMENT AND MAPPING**

LAKE MASSAPOAG
SHARON, MA

TITLE:

WATER QUALITY SAMPLING LOCATIONS

DRAWN BY:	J. BERTHERMAN	PROJ. NO.:	481848.0000.0000
CHECKED BY:	S. DEHAINAUT	**FIGURE #1**	
APPROVED BY:	M. LADEWIG		
DATE:	NOVEMBER 2022		

TRC

10 HEMINGWAY DRIVE
2ND FLOOR
EAST PROVIDENCE, RI 02915
PHONE: 401.330.1236

FILE: 481848_MASSAPOAG

Secchi disk was collected from the surface of the lake. Where water depth was sufficient, water temperature, dissolved oxygen, and specific conductance were measured at one-meter intervals for a vertical profile of the water column. Turbidity and pH were collected near the surface and bottom of the water column.

Additionally, water quality grab samples were collected at each of the sampling locations and sent to a state-certified laboratory to be analyzed for the following:

- Total phosphorus
- Total dissolved (soluble) phosphorus – field filtered to extend laboratory holding time
- Total nitrogen (total Kjeldahl nitrogen [TKN], nitrate, and nitrite)

Select samples were also analyzed for one or more of the following, as summarized in Table1:

- Chlorophyll a
- Phytoplankton identification and enumeration
- Ammonia nitrogen (a subset of TKN)
- Total iron

Grab sample volumes varied from 125 mL for phytoplankton to 2 L for chlorophyll a, as dictated by laboratory requirements. The Deep Hole – Bottom sample was collected using a van Dorn bottle with a depth-calibrated rope.

Table 1. 2022 Data Collected by Sampling Dates and Locations

Date/ Location	Water Quality								Sediment Quality
	Field Measurements	Total P	Total Dissolved P	Total N	Chlorophyll a	Phytoplankton	Ammonia-N	Iron	P Fractionation
June 2									
Deep Hole - Surface	Y	Y	Y	Y	N	N	N	N	N
Deep Hole – Bottom	Y	Y	Y	Y	N	N	N	N	N
Fletcher's Cove	Y	Y	Y	Y	N	N	N	N	N
Lagoon Inlet to South Cove	Y	Y	Y	Y	N	N	N	N	N
July 26									
Deep Hole - Surface	Y	Y	Y	Y	Y	Y	N	N	N
Deep Hole – Bottom	Y	Y	Y	Y	N	N	N	N	N
Fletcher's Cove	Y	Y	Y	Y	N	N	N	N	N
South Cove	Y	Y	Y	Y	N	N	N	N	N
Horton's Cove	Y	Y	Y	Y	N	N	N	N	N

Date/ Location	Water Quality								Sediment Quality
	Field Measurements	Total P	Total Dissolved P	Total N	Chlorophyll a	Phytoplankton	Ammonia-N	Iron	P Fractionation
October 3									
Deep Hole - Surface	Y	Y	Y	Y	Y	Y	Y	Y	N
Deep Hole – Bottom	Y	Y	Y	Y	N	N	Y	Y	Y
Fletcher's Cove	Y	Y	Y	Y	N	N	Y	Y	N
South Cove	Y	Y	Y	Y	N	N	Y	Y	N
Horton's Cove	Y	Y	Y	Y	N	N	Y	Y	N

Sediment Sampling

TRC collected one sediment sample at the deep hole of Lake Massapoag on October 3, 2022 and submitted it for phosphorus fractionation analysis (Table 1). The sample was collected using a 6-inch x 6-inch x 6-inch Ekman grab sampler. Once the sample was retrieved onto the vessel, a subsample was extracted from the undisturbed sample using a 2.75-inch diameter polycarbonate core liner inserted through the flaps at the top of the sampler. This allowed TRC to capture a representative sample from the top layer of sediment.

The target of the sediment sampling was phosphorus. A typical sediment sample will contain multiple phosphorus forms (fractions) in differing proportions. Therefore, it is important to understand not just the total amount of phosphorus in the sediments but also the amount contributed by each fraction. Sediment samples were sent to the BEC Engineering & Geology laboratory and processed using a methodology modified from Psenner et al. (1988) to obtain the each of the follow phosphorus fractions:

- Mobile phosphorus (including iron-bound phosphorus)
- Organic phosphorus
- Calcium-bound phosphorus
- Aluminum-bound phosphorus

These fractions were analyzed to improve understanding of the potential for internal loading of phosphorus from the sediments of Lake Massapoag.

Plant Mapping

At the request of the Town, plant mapping was completed during the October 3, 2022 visit to allow sufficient time for diver-assisted suction harvesting (DASH) work to be completed by a separately contracted vendor. Although this date falls outside the peak of development for most aquatic plant species, weather conditions were mild and most summer-maturing aquatic plants would still be expected to be present into early October.

TRC used plant rakes and direct observation to map the aquatic vegetative community composition, cover (percent of bottom occupied), and biovolume (percent of water column with vegetative growth) in areas shallow enough to support vascular plant life. 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 plants)
- 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 using a GPS receiver and field sketches.

Results

Water Quality

Water quality results for Lake Massapoag are discussed by parameter in this section. However, it should be noted that the water quality results presented in this report represent three snapshots of water quality in the lake during an abnormally dry period, with most of eastern Massachusetts classified as being in significant to critical drought status from late spring to early autumn. Each of these parameters should be expected to vary on a daily, seasonal, and interannual basis. Some, such as dissolved oxygen, may vary substantially over the course of a single day.

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 Massapoag, the observed dissolved oxygen concentrations met the state standard for warmwater fisheries through most of the water column in June and October (Table 2). However, at the peak of summer (July) dissolved oxygen concentrations only met the state standard in the upper four meters of the water column. Below this depth, conditions were hypoxic (low dissolved oxygen) to anoxic (no dissolved oxygen). Anoxic conditions at depth reduce the amount of usable habitat volume for aquatic life in Lake Massapoag during the summer months. Additionally, long periods of anoxia can lead to chemical reactions that favor internal loading of phosphorus from the sediments. The development of anoxia in Lake Massapoag is likely due to the formation of a strong thermal stratification in the lake (a natural process whereby warm water overlays cold water and inhibits vertical mixing) combined with a high oxygen demand (a factor exacerbated by human-induced eutrophication). This results in a physical separation of surface and bottom waters and the eventual depletion of dissolved oxygen in the bottom waters.

The vertical temperature profile on October 3 indicates that the thermal stratification observed in June and July was no longer present. This breakdown in stratification allowed dissolved oxygen to be reintroduced into most of the deep waters of Lake Massapoag.

Specific Conductance

Conductivity is a measure of dissolved ions (salts) in the water but its value varies with temperature. Therefore, conductivity is often expressed as specific conductance, which is an expression of this value when standardized to 25 °C. Although there are no state numerical standards for specific conductance, measurements above 100 µS/cm are typically 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.

Measurements of specific conductance at Lake Massapoag ranged from 162.2 to 202.7 µS/cm although the higher number probably reflects interaction of the probe with the sediment-water interface. Most readings were under 180 µS/cm (Tables 2 and 3). These measurements are far from extreme but indicate that human activity has likely had some impact on water quality in the lake.

Table 2. 2022 Field-Measured Water Quality Data at Deep Hole

Depth (m)	June 2						July 26						October 3					
	DO (mg/L)	DO (%)	SC. (µS/cm)	Temp (C)	pH (SU)	Turb (NTU)	DO (mg/L)	DO (%)	SC. (µS/cm)	Temp (C)	pH (SU)	Turb (NTU)	DO (mg/L)	DO (%)	SC. (µS/cm)	Temp (C)	pH (SU)	Turb (NTU)
0.5	9.52	109.0	164.7	21.6	7.2	0.005	7.23	92.5	172.6	27.5	7.2	1.95	8.70	87.8	170.6	15.9	7.2	1.89
1	9.48	109.4	164.7	21.6	-	-	7.21	91.8	172.6	27.5			8.56	86.5	170.7	15.9		
2	9.56	109.8	164.6	21.6	-	-	7.15	89.8	172.4	27.3			8.57	86.5	170.6	15.9		
3	9.66	111.1	164.5	21.6	-	-	6.88	86.0	172.4	27.2			8.6	86.7	170.7	15.9		
4	8.91	101.7	165.6	21.1	-	-	6.55	82.9	172.6	26.9			8.56	87.0	170.6	15.9		
5	7.50	79.0	164.3	17.2	-	-	2.97	34.4	172.6	25.0			8.67	87.3	170.6	15.9		
6	6.80	66.7	162.5	14.3	-	-	0.14	1.4	183.3	21.3			8.63	87.0	170.6	15.9		
7	7.08	68.6	162.2	13.3	-	-	0.05	0.5	185.1	17.6			8.57	86.2	170.6	15.9		
8	7.03	67.8	162.2	13.1	-	-	0.04	0.4	180.0	15.0			8.53	86.3	170.6	15.9		
9	6.81	65.5	162.5	12.8	-	-	0.04	0.4	179.2	14.7			8.59	86.6	170.6	15.9		
10	6.61	63.3	163.2	12.7	-	-	0.03	0.3	176.8	12.9			8.65	87.1	170.6	15.8		
11	2.19	21.4	163.6	12.6	-	-	0.03	0.3	179.8	12.6			8.68	87.4	170.6	15.8		
12	0.59	6.0	163.4	12.7	6.3	0.32	0.02	0.2	186.1	12.5	6.9	1.58	3.38	3.4	172.1	15.4	7.0	1.76
13	0.40	4.0	202.7	13.0	-	-	0.02	0.2	187.1	12.4			0.10	0.9	179.8	15.2		

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). Therefore, a single snapshot 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.

Lake Massapoag had a pH that varied from 6.3 to 8.2 SU, although most readings were slightly acidic to slightly basic (Tables 2 and 3). Although the low end of this range falls outside the numerical standard, these values are not unusual for softwater lakes in eastern Massachusetts and are likely to be near the natural background range of the lake.

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 impair any use assigned to this class.

Turbidity in Lake Massapoag ranged from almost undetectable to a high of 2.21 NTU (Tables 2 and 3). These are typically not considered to be indicative of excessive turbidity levels.

Table 3. 2022 Field-Measured Water Quality Data at Shallow Locations*

Location/ Depth (m)	June 2						July 26						October 3					
	DO (mg/L)	DO (%)	SC. (µS/cm)	Temp (C)	pH (SU)	Turb (NTU)	DO (mg/L)	DO (%)	SC. (µS/cm)	Temp (C)	pH (SU)	Turb (NTU)	DO (mg/L)	DO (%)	SC. (µS/cm)	Temp (C)	pH (SU)	Turb (NTU)
Fletcher's Cove																		
0.5	9.7	115.3	164.8	23	6.9	0.40	7.33	94.4	172.8	27.4	7.0	1.72	9.52	91.1	170.9	13.3	7.6	2.21
1	-	-	-	-	-	-	7.18	89.9	173.2	27.4	-	-	9.46	90.1	170.9	13.4	-	-
Lagoon Inlet																		
0.5	8.4	99.3	165.4	23.2	6.3	0.18	-	-	-	-	-	-	-	-	-	-	-	-
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
South Cove																		
0.5	-	-	-	-	-	-	7.13	91.5	172.1	27.6	7.2	1.67	9.20	88.7	170.8	13.9	7.4	1.65
1	-	-	-	-	-	-	7.34	93.8	172.4	27.6	-	-	9.17	88.5	170.8	13.9	-	-
Horton's Cove																		
0.5	-	-	-	-	-	-	6.71	84.6	172.8	27.5	7.1	1.98	8.98	88.1	170.6	14.5	8.2	2.06
1	-	-	-	-	-	-	7.65	97.2	171.5	27.3	-	-	9.12	89.3	170.7	14.5	-	-
2	-	-	-	-	-	-	-	-	-	-	-	-	9.08	88.6	170.7	14.5	-	-

*Secchi disk on bottom at all locations on all dates

Transparency

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.

Secchi disk transparency at Lake Massapoag was 2.0 m on June 2, 3.0 m on July 26, and 2.0 m on October 3 (i.e., average of 2.3 m). These values are intermediate and may reflect some reduction due to water color, particulates, and/or algal growth.

Nutrients

High levels of nutrients (e.g., nitrogen and phosphorus) in the water column can lead to undesirable biological consequences. For example, floating plants like duckweed and watermeal may grow to excessive levels when soluble inorganic nitrogen (e.g., nitrate, ammonia) and phosphorus are present at high concentrations. Likewise, high levels of these nutrients may also trigger excessive algal growth, leading to bloom conditions and, under certain conditions, dominance by harmful species of cyanobacteria. Phosphorus tends to be the limiting nutrient in freshwater lakes 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 harmful cyanobacteria blooms to develop, which can result in taste and odor issues or production of cyanotoxins, such as microcystin. For these reasons, phosphorus is generally considered to be undesirable in water bodies that are used for recreation.

Although there is no statewide phosphorus standard for Class B waters, lower concentrations are generally preferable and concentrations greater than 0.025 mg/L are typically considered excessive.

The total phosphorus concentration in Lake Massapoag ranged from 0.014 mg/L to 0.087 mg/L (Table 4), resulting in an average of 0.035 mg/L. This suggests that the total phosphorus concentration at Lake Massapoag is higher than desirable for a recreational water body and may contribute to management issues.

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. Therefore, if phosphorus is plentiful, these organisms can produce the nitrogen they need to continue rapid growth. Likewise, nitrogen can be removed from the lake system 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, lower concentrations are generally preferable and total nitrogen concentrations in excess of 1.0 mg/L are often indicative of excessive anthropogenic sources.

The total nitrogen concentration in Lake Massapoag ranged from 0.40 mg/L to 0.90 mg/L (Table 4) and therefore do not initially appear to be indicative of excessive anthropogenic sources. In all samples, total Kjeldahl nitrogen (TKN), which includes both ammonia and organic nitrogen, was the primary form of nitrogen observed. Of the two, ammonia nitrogen is the more biologically available form and can be readily taken up by most plants and algae.

Ammonia nitrogen was only sampled during the October 3 round of sampling and was generally not found to be present at high levels, except at Fletcher’s Cove, where it constituted a substantial portion of the total TKN (Table 4). The remainder of the TKN was composed of organic nitrogen, most likely from natural sources (plant matter, algal cells, etc.).

One additional way to evaluate phosphorus and nitrogen levels in a water body is by examining the ratio of one to the other. The Redfield ratio posited an average ratio of atoms for each of the key nutrients in algal cells (Redfield 1958). Although originally developed for marine phytoplankton, this ratio provides a framework through which to interpret the abundance of phosphorus and nitrogen relative to each other. Compared to the Redfield ratio, most samples collected from Lake Massapoag were well above the 16:1 ratio theorized for nitrogen atoms to phosphorus atoms (average of 46:1). This suggests that the lake was likely to be phosphorus-limited (i.e., nitrogen was plentiful relative to phosphorus) over the course of the 2022 growing season. Under these conditions, phosphorus becomes the nutrient that controls (or limits) the growth of phytoplankton in the lake. Therefore, the addition of more phosphorus would be likely to result in increased production of phytoplankton.

This is not atypical for freshwater lakes and ponds and is one of the reasons that phosphorus is usually the focus of nutrient management programs.

Similarly, the ratio of iron to phosphorus may be used to develop a rough estimate of whether iron levels are sufficient to effectively bind phosphorus under aerobic conditions (Jensen et al. 1992). Lakes with ratios lower than 15:1 (by weight) may be considered iron-poor relative to phosphorus. The ratio of iron to phosphorus in Lake Massapoag averaged 9:1, which suggests that iron may not be able to capture all phosphorus, even under well-oxygenated conditions.

Table 4. 2022 Water Quality Analytical Data

Date/ Location	Depth (m)	Total P (mg/L)	Dissolved P (mg/L)	Total N					Chlorophyll a (mg/m^3)	Iron (mg/L)
				TKN (mg/L)			Nitrate-N (mg/L)	Nitrite-N (mg/L)		
				Total	Organic-N (mg/L)*	Ammonia - N (mg/L)				
June 2										
Deep Hole -Surface	0.5	0.045	0.046	0.44	-	-	<0.010	<0.02	-	-
Deep Hole – Bottom	12	0.057	0.091	0.60	-	-	<0.010	0.05	-	-
Fletcher's Cove	0.5	0.057	0.018	0.41	-	-	<0.010	<0.02	-	-
Lagoon Inlet to South Cove	0.5	0.056	0.052	0.40	-	-	<0.010	<0.02	-	-
July 26										
Deep Hole -Surface	0.5	0.017	0.010	0.41	-	-	<0.010	<0.02	4.20	-
Deep Hole – Bottom	12	0.022	0.013	0.89	-	-	0.014	<0.02	-	-
Fletcher's Cove	0.5	0.022	0.007	0.41	-	-	<0.010	<0.02	-	-
South Cove	0.5	0.014	0.006	0.41	-	-	<0.010	<0.02	-	-
Horton's Cove	0.5	0.014	0.005	0.47	-	-	<0.010	<0.02	-	-
October 3										
Deep Hole -Surface	0.5	0.018	0.017	0.54	0.47	0.07	<0.010	<0.02	4.78	0.293
Deep Hole – Bottom	12	0.031	0.013	0.46	0.46	<0.05	<0.010	<0.02	-	0.263
Fletcher's Cove	0.5	0.027	0.021	0.87	0.51	0.36	<0.010	<0.02	-	0.222
South Cove	0.5	0.087	0.012	0.51	0.51	<0.05	<0.010	<0.02	-	0.196
Horton's Cove	0.5	0.021	0.02	0.51	0.41	0.10	<0.010	<0.02	-	0.216

*Calculated as TKN minus Ammonia-N

Chlorophyll A

Algal density can be inferred by measuring chlorophyll a, the primary photosynthetic pigment found in most algal cells. Although there is no statewide chlorophyll a standard for Class B waters, high chlorophyll a levels are generally considered undesirable because they are associated with elevated algal production and eutrophic conditions.

The average chlorophyll a concentration in Lake Massapoag was 4.49 mg/m^3 (Table 4). This is indicative of moderate levels of algal growth. However, the small sample size (two samples) suggests that this should be interpreted cautiously.

Phytoplankton

The phytoplankton samples collected from Lake Massapoag contained chrysophtyes, cryptophytes, cyanobacteria, diatoms, dinoflagellates, euglenoids, and green algae (Table 5). The majority of phytoplankton observed in both the July 26 and October 3 samples was contributed by diatoms, although the October 3 sample contained a taxonomically richer community. This is not unexpected, as diatoms benefit from the mixing of silicon into the water column during autumn turnover. Cyanobacteria were present in both samples but constituted less than ten percent of the total phytoplankton community biovolume.

Table 5. Phytoplankton Collected from Lake Massapoag

Group	Taxon	Biovolume μm^3/mL		% Contribution		Cell Count – cells/mL (Potentially Toxigenic Cyanobacteria only)	
		July 26	October 3	July 26	October 3	July 26	October 3
cyanobacteria	*Anabaena (Dolichospermum) flos-aquae*	0	2,098	0	1.9		31
cyanobacteria	*Aphanothece sp.*	1,691	188	1.7	0.2		
cyanobacteria	*Microcystis aeruginosa*	5,638	6,013	5.7	5.4	705	752
chrysophyte	*Chrysococcus rufescens*	0	799	0	0.7		
chrysophyte	*Kephyrion littorale*	893	0	0.9	0		
chrysophyte	*Kephyrion sp.*	0	395	0	0.4		
chrysophyte	*Kephyrion spirale*	0	395	0	0.4		
chrysophyte	*Mallomonas sp.*	0	4,761	0	4.3		
cryptophyte	*Cryptomonas erosa*	21,986	17,915	22.2	16.1		
cryptophyte	*Rhodomonas minuta*	5,638	4,072	5.7	3.7		
diatom	*Cyclotella comta*	0	21,329	0	19.2		
diatom	*Cymbella minuta*	0	1,159	0	1.0		
diatom	*Epithemia turgida*	19,966	0	20.2	0		
diatom	*Fragilaria construens venter*	0	150	0	0.1		
diatom	*Fragilaria crotonensis*	0	2,631	0	2.4		
diatom	*Nitzschia frustulum*	0	376	0	0.3		
diatom	*Synedra rumpens*	0	2,631	0	2.4		
diatom	*Tabellaria fenestrata*	22,550	15,033	22.8	13.5		
diatom	*Tabellaria flocculosa*	0	1,848	0	1.7		
dinoflagellate	*Glenodinium sp.*	0	2,192	0	2.0		
euglenoid	*Trachelomonas hispida*	9,866	0	10.0	0		

Group	Taxon	Biovolume µm³/mL		% Contribution		Cell Count – cells/mL (Potentially Toxigenic Cyanobacteria only)	
		July 26	October 3	July 26	October 3	July 26	October 3
euglenoid	*Trachelomonas volvocina*	0	23,615	0	21.3		
green	*Ankistrodesmus falcatus*	117	78	0.1	0.1		
green	*Chlamydomonas sp.*	3,054	0	3.1	0		
green	*Oocystis pusilla*	1,015	338	1.0	0.3		
green	*Sphaerocystis schroeteri*	6,577	2,960	6.6	2.7		

Sediment Sampling

Based on the laboratory results received from BEC, iron-bound and loosely sorbed phosphorus represented the second largest fraction of phosphorus in sediments at the Deep Hole location (Table 6). Most of this fraction is likely to be iron-bound phosphorus based on sampling conducted in other eastern Massachusetts lakes (e.g., Wagner et al. 2017), which is the most readily released from sediments when dissolved oxygen conditions are low, as they were observed to be in the deepest waters of Lake Massapoag during TRC's 2022 sampling program. Therefore, it can be thought of as seasonally mobile phosphorus – readily releasing from sediments into the water column when dissolved oxygen levels are low and then precipitating out of the water column and back to the sediments when dissolved oxygen levels are high. Although the concentration of mobile phosphorus in Lake Massapoag sediments is not considered extreme, it is high enough that it could constitute a significant internal source of phosphorus, if it is indeed representative of broader sediment conditions in deep portions of the lake.

The largest phosphorus fraction was bound to calcium and the third largest to aluminum, both of which are effective at binding phosphorus under the anoxic conditions observed in deep waters of Lake Massapoag. However, calcium is sensitive to pH and may be less effective at pH levels below 5.5 SU. The lowest pH reading observed by TRC in bottom waters of Lake Massapoag was 6.3 SU. This is not problematically low but does suggest that calcium-bound phosphorus may also have the potential to be released from sediments on a limited basis (when pH falls below 5.5).

Organically bound phosphorus was the smallest fraction in the Lake Massapoag sediment sample. Although this fraction releases over time as organic matter decays, the rate of release is a function of temperature and typically does not result in substantial contribution to internal loading in deep lakes.

Table 6. Sediment Sampling Results from Lake Massapoag

Sediment Sample ID	% Moisture	% Organic Solids	% Inorganic Solids	Iron and Loosely Sorbed P (mg/kg dry weight)	Organically Bound P (mg/kg dry weight)	Calcium Bound P (mg/kg dry weight)	Aluminum Bound P (mg/kg dry weight)	Total P (mg/kg dry weight)
Deep Hole	84%	18%	82%	260	176	363	192	991

Plant Mapping

Aquatic plant cover in Lake Massapoag was primarily limited to water shallower than 10 feet. The most extensive areas of aquatic plants were found along the southern and western shorelines, although some beds were also present near the northeastern shoreline of the lake. Approximately 5.8 acres were classified as dense or very dense growth with a plant cover value greater than 50% (Figure 2). The densest growth was found in the Lagoon just east of South Cove.

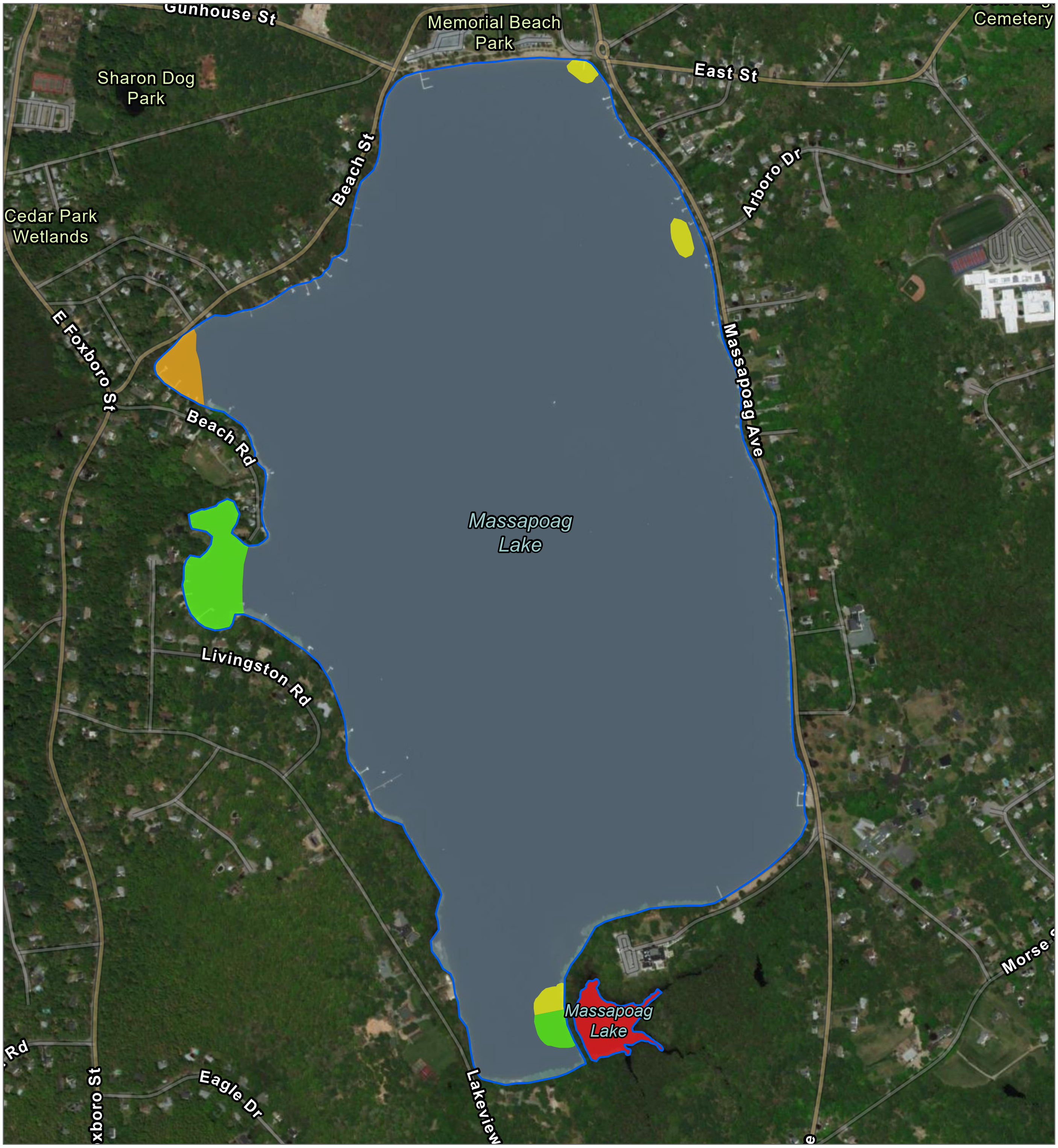
Aquatic plant biovolume was generally low for the majority of the observed plant beds (Figure 3). This suggests that most of the lake was dominated by low growing species or contained plants that were in poor condition. The primary exception to this was the Lagoon which hosted approximately 3.7 acres of high biovolume plant beds (i.e., greater than 50% of the water column occupied).

The aquatic plant community observed at Lake Massapoag consisted of ten species, three of which are invasive exotic species (Table 6). Two of the three invasives, fanwort (*Cabomba caroliniana*) and variable-leaf milfoil (*Myriophyllum heterophyllum*), are often associated with the formation of high-biovolume, nuisance-level beds. In contrast, the third invasive species, mudmat (*Glossostigma cleistanthum*), while capable of forming extensive beds, is diminutive in size. Each of the aquatic invasive species are further profiled in subsections below.

The most frequently observed native aquatic plant species included spikerush (*Eleocharis* sp.), stonewort (*Nitella* sp. – actually a type of macroalgae), watershield (*Brasenia schreberi*), and white water lily (*Nymphaea odorata*). Within Lake Massapoag proper, white water lily and watershield were mostly concentrated in the northern portion of Fletcher's Cove. Although not observed at problematic biovolumes, spikerush was present in some of the denser vegetation observed in Horton's Cove, while water celery (*Vallisneria americana*) was present near the Arboro Drive shoreline, and floating-leaf pondweed was documented near the flume house at the northeastern end of the lake. Although a state-listed species is known to occur in the lake, mapping the presence of this species was beyond the scope of TRC's surveys for 2022.

Table 6. Aquatic Plants Observed at Lake Massapoag

Common Name	Scientific Name	Growth Habit	Status
Fanwort	*Cabomba caroliniana*	Submerged	Exotic
Floating-leaf Pondweed	*Potamogeton epihydrus*	Floating-leaved	Native
Marsh Seedbox	*Ludwigia palustris*	Submerged/Emergent	Native
Mudmat	*Glossostigma cleistanthum*	Submerged/Emergent	Exotic
Spikerush	*Eleocharis sp.*	Submerged/Emergent	Native
Stonewort	*Nitella sp.*	Submerged	Native Macroalga
Variable-leaf Milfoil	*Myriophyllum heterophyllum*	Submerged	Exotic
Water Celery	*Vallisneria americana*	Submerged	Native
Watershield	*Brasenia schreberi*	Floating-leaved	Native
White Water Lily	*Nymphaea odorata*	Floating-leaved	Native



TOTAL PLANT COVERAGE

- 0% (378.8 ACRES)
- 1% - 25% (7.09 ACRES)
- 26% - 50% (1.91 ACRES)
- 51% - 75% (2.13 ACRES)
- 76% - 100% (3.67 ACRES)

BASE MAP: ESRI, WORLD IMAGERY, 2022
DATA SOURCES:
TRC, GPS LOCATIONS, 10/03/22
MASSGIS, HYDROGRAPHY, 2019

N

0 500 1,000 FEET

1:11,500 1" = 958'

PROJECT: LAKE ASSESSMENT AND MAPPING
LAKE MASSAPOAG
SHARON, MA

TITLE: TOTAL PLANT COVERAGE
OCTOBER 3, 2022 SURVEY

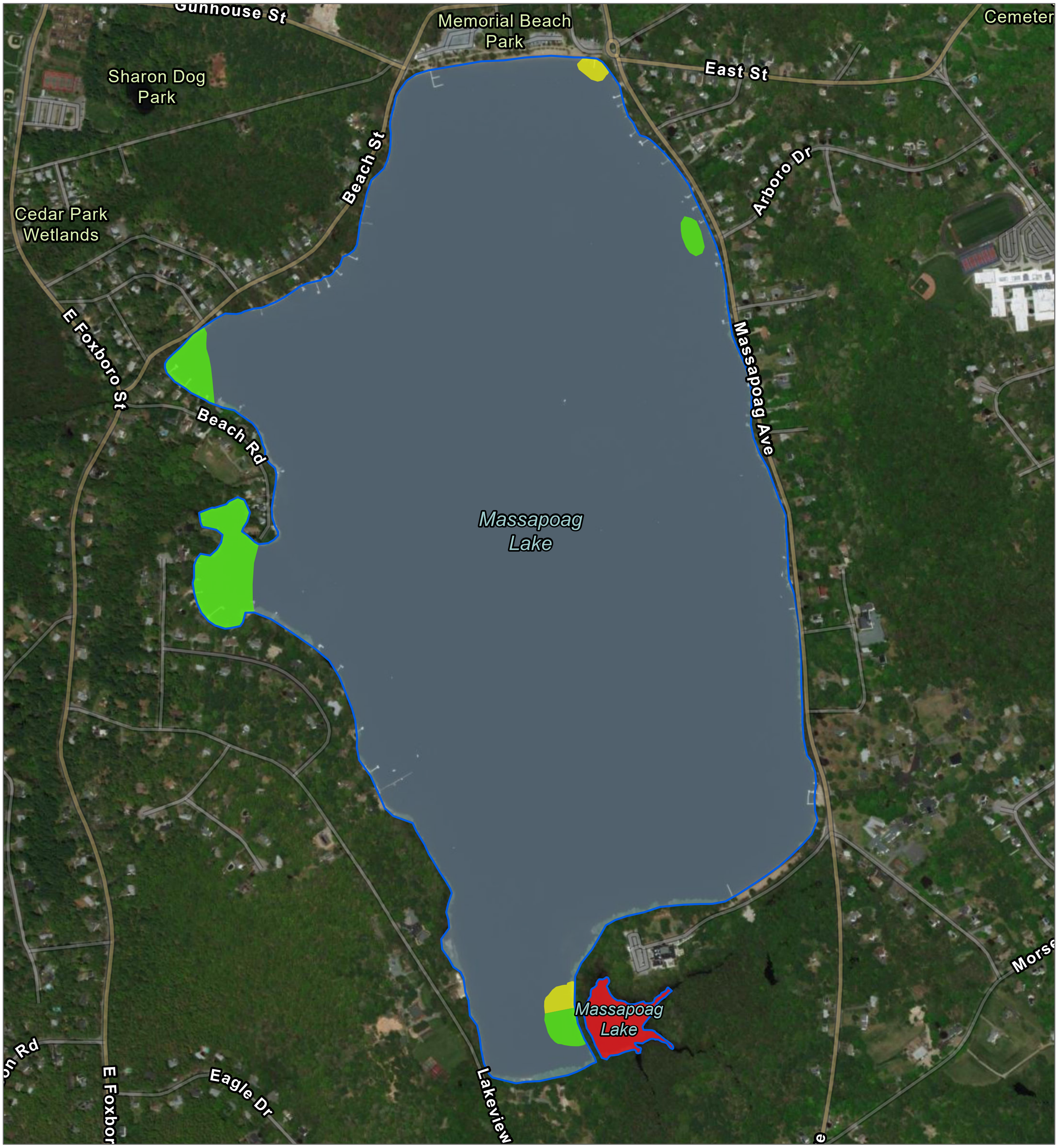
DRAWN BY:	J. BERTHERMAN	PROJ. NO.:	481848.0000.0000
CHECKED BY:	S. DEHAINAUT	FIGURE #2	
APPROVED BY:	M. LADEWIG		
DATE:	NOVEMBER 2022		

TRC

10 HEMINGWAY DRIVE
2ND FLOOR
EAST PROVIDENCE, RI 02915
PHONE: 401.330.1236

FILE: 481848_MASSAPOAG

COORDINATE SYSTEM: NAD 1983 STATEPLANE MASSACHUSETTS MAINLAND FIPS 2001 FEET; MAP ROTATION: 0
-- SAVED BY: JBERTHERMAN ON 11/4/2022, 09:56:19 AM; FILE PATH: T:\1-PROJECTS\TOWNOFSHARONMA\481848_BASELINEMONITORING\2-APRX\481848_MASSAPAUG\481848_MASSAPAUG.APRX; LAYOUT NAME: 481848_TOTALCOVER



TOTAL PLANT BIOVOLUME

- 0% (387.81 ACRES)
- 1% - 25% (9.96 ACRES)
- 26% - 50% (1.24 ACRES)
- 51% - 75% (0 ACRES)
- 76% - 100% (3.67 ACRES)

BASE MAP: ESRI, WORLD IMAGERY, 2022
DATA SOURCES:
TRC, GPS LOCATIONS, 10/03/22
MASSGIS, HYDROGRAPHY, 2019

N

0 500 1,000 FEET

1:11,500 1" = 958'

PROJECT: LAKE ASSESSMENT AND MAPPING
LAKE MASSAPOAG
SHARON, MA

TITLE: TOTAL PLANT BIOVOLUME
OCTOBER 3, 2022 SURVEY

DRAWN BY:	J. BERTHERMAN	PROJ. NO.:	481848.0000.0000
CHECKED BY:	S. DEHAINAUT	FIGURE #3	
APPROVED BY:	M. LADEWIG		
DATE:	NOVEMBER 2022		

TRC
10 HEMINGWAY DRIVE
2ND FLOOR
EAST PROVIDENCE, RI 02915
PHONE: 401.330.1236

FILE: 481848_MASSAPOAG

COORDINATE SYSTEM: NAD 1983 STATEPLANE MASSACHUSETTS MAINLAND FIPS 2001 FEET; MAP ROTATION: 0
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Fanwort

Fanwort (*Cabomba caroliniana*) is a submerged aquatic invasive plant that can form dense and extensive beds in water as deep as 15 to 20 feet. The finely divided underwater leaves are fanlike and arranged oppositely along the stem. Fanwort is slow to develop in spring and does not typically become evident near the surface of the water column until mid- to late summer. However, at that time small white flowers may extend above the surface. This is when fanwort is the most noticeable and impactful on recreational activity.

Fanwort is a hardy and persistent species that regrows and spreads each year from perennial root crowns. The species can also spread when stem fragments become rooted in bottom sediments. Within two to three years of initial invasion, it can become established, displacing native species and forming extensive monocultures in suitable habitats.

Fanwort was the primary aquatic invasive species observed at Lake Massapoag, covering approximately 3% (11.45 acres) of the lake. The areas with densest growth were the South Cove (2.12 acres) and the adjacent Lagoon (3.67 acres). However, some sparse beds and widely scattered clumps were also found in shallow waters of Fletcher's Cove, which contained approximately 5.0 acres of very light fanwort cover (Figure 4).

Mudmat

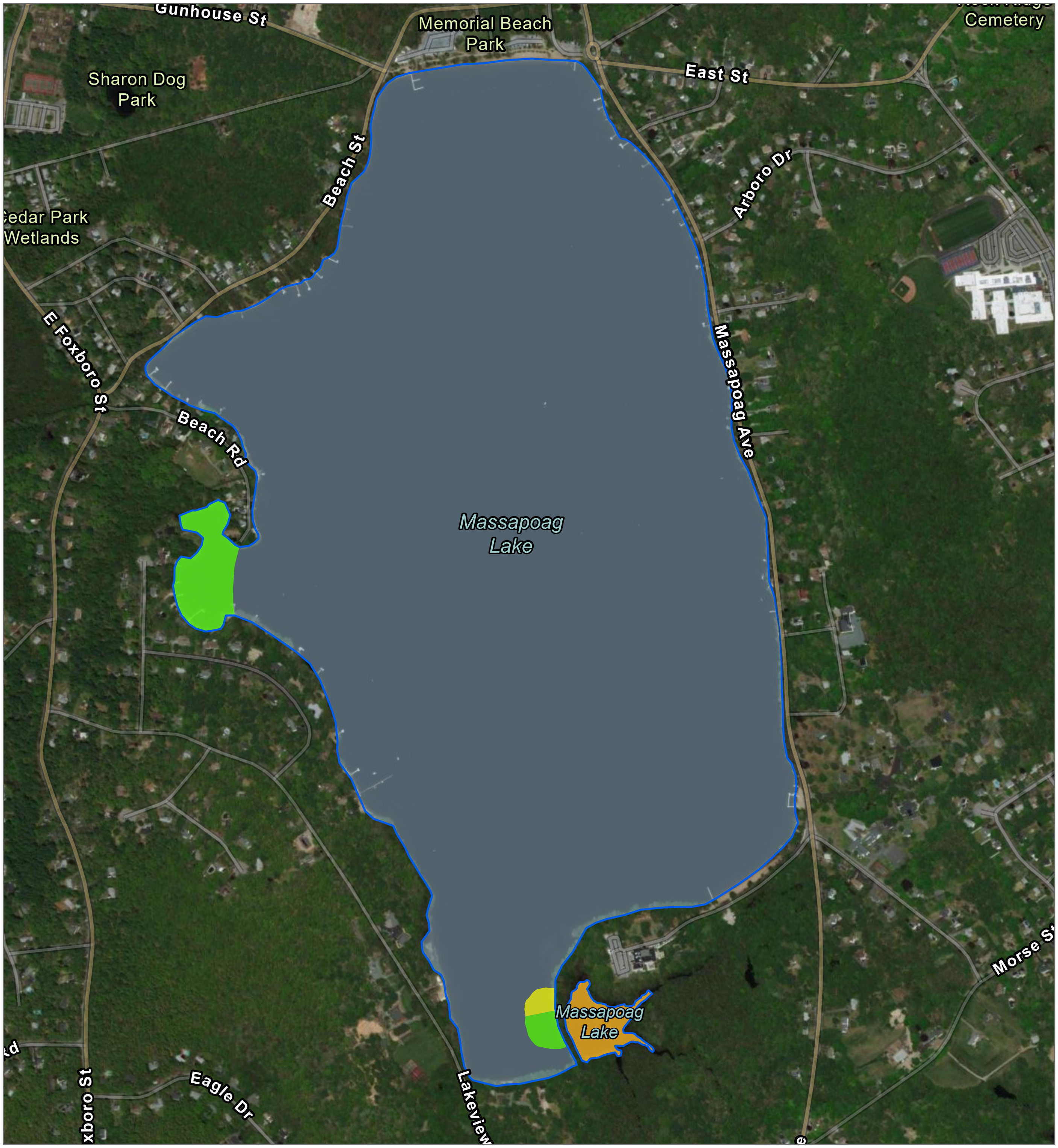
Mudmat (*Glossostigma cleistanthum*) is an invasive species that forms dense mats in the littoral zone. Although diminutive in height, it readily spreads horizontally with tiny pairs of leaves arising from stems. Mudmat can also survive as an emergent for short periods if it is exposed by receding waters.

Mudmat was primarily documented in shallow waters along the eastern shoreline of the South Cove (Figure 5), although TRC understands that this plant was also recently sighted by residents elsewhere in the lake. Ultimately, given the minute size of this plant the impact of this species on lake water quality and ecology is unlikely to be significant.

Individual mudmat plants are diminutive in size, although colonies can extend over large areas.

Variable-leaf Milfoil

Variable-leaf milfoil (*Myriophyllum heterophyllum*) is a submerged invasive aquatic plant with densely packed, feather-like leaves whorled around a main stem. This species can form dense mats and grow in up to 15 feet of water. Like fanwort, variable-leaf milfoil is a hardy perennial and can become established in a range of aquatic habitats but prefers slow moving waters. Once established, variable-leaf milfoil is a high impact invasive species, outcompeting native species and producing dense, high-biovolume beds. These beds often reach the surface early in the summer; flowering stems may also extend above the water for a period in mid- to late summer, resulting in substantial interference with recreation.



FANWORT COVERAGE

- 0% (382.16 ACRES)
- 1% - 25% (7.09 ACRES)
- 26% - 50% (0.69 ACRES)
- 51% - 75% (3.67 ACRES)
- 76% - 100% (0 ACRES)

BASE MAP: ESRI, WORLD IMAGERY, 2022
DATA SOURCES:
TRC, GPS LOCATIONS, 10/03/22
MASSGIS, HYDROGRAPHY, 2019

0 500 1,000 FEET

1:11,500 1" = 958'

PROJECT: **LAKE ASSESSMENT AND MAPPING**
LAKE MASSAPOAG
SHARON, MA

TITLE: **FANWORT COVERAGE**
OCTOBER 3, 2022 SURVEY

DRAWN BY:	J. BERTHERMAN	PROJ. NO.:	481848.0000.0000
CHECKED BY:	S. DEHAINAUT	**FIGURE #4**	
APPROVED BY:	M. LADEWIG		
DATE:	NOVEMBER 2022		

TRC
10 HEMINGWAY DRIVE
2ND FLOOR
EAST PROVIDENCE, RI 02915
PHONE: 401.330.1236

FILE: 481848_MASSAPOAG

COORDINATE SYSTEM: NAD 1983 STATEPLANE MASSACHUSETTS MAINLAND FIPS 2001 FEET; MAP ROTATION: 0
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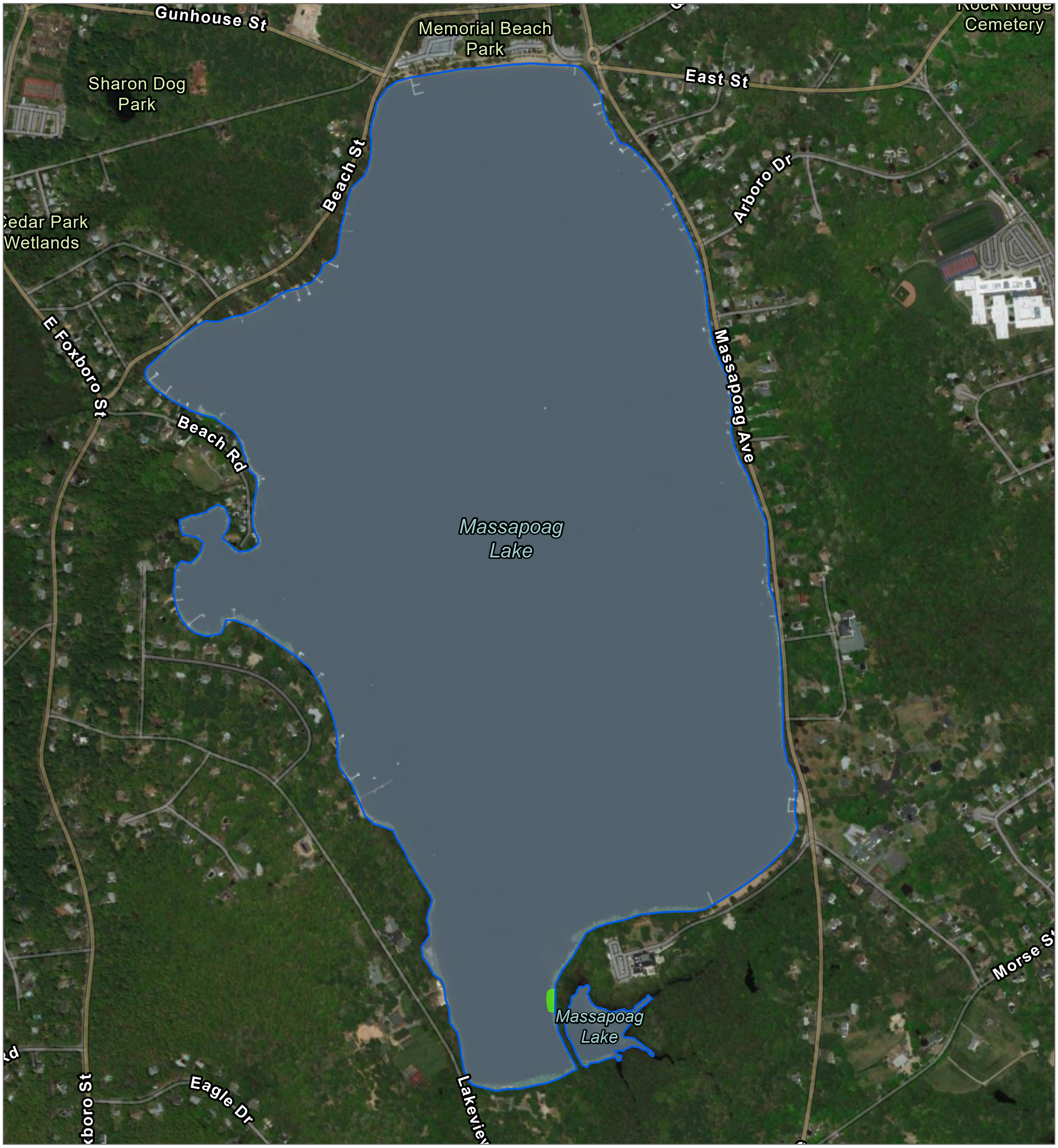

MUD-MAT COVERAGE

- 0% (393.42 ACRES)
- 1% - 25% (0.19 ACRES)
- 26% - 50% (0 ACRES)
- 51% - 75% (0 ACRES)
- 76% - 100% (0 ACRES)

PROJECT: **LAKE ASSESSMENT AND MAPPING**

LAKE MASSAPOAG
SHARON, MA

TITLE: **MUD-MAT COVERAGE**
OCTOBER 3, 2022 SURVEY

DRAWN BY:	J. BERTHERMAN	PROJ. NO.:	481848.0000.0000
CHECKED BY:	S. DEHAINAUT	**FIGURE #5**	
APPROVED BY:	M. LADEWIG		
DATE:	NOVEMBER 2022		

BASE MAP: ESRI, WORLD IMAGERY, 2022
DATA SOURCES:
TRC, GPS LOCATIONS, 10/03/22
MASSGIS, HYDROGRAPHY, 2019

N

0 500 1,000 FEET

1:11,500 1" = 958'

TRC

10 HEMINGWAY DRIVE
2ND FLOOR
EAST PROVIDENCE, RI 02915
PHONE: 401.330.1236

FILE: 481848_MASSAPOAG

COORDINATE SYSTEM: NAD 1983 STATEPLANE MASSACHUSETTS MAINLAND FIPS 2001 FEET; MAP ROTATION: 0 LAYOUT NAME: 481848_MUDMAT
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Although it has been previously documented in Lake Massapoag, living beds of this species were not directly observed by TRC during the plant mapping event in October 2022. However, some dead stems were found in the South Cove, near the Lagoon inlet.

Recommendations for 2023

Management Issues

The conditions TRC observed during our field assessments suggest that water quality in Lake Massapoag may be impacted by the following management issues:

- Cultural eutrophication (i.e., human-induced nutrient enrichment), which may lead to excessive phytoplankton growth and a higher likelihood of cyanobacteria blooms.
- Extended periods of hypolimnetic anoxia (i.e., deepwater dissolved oxygen depletion), which alters water chemistry and may induce sediment release of phosphorus.
- Presence of three aquatic invasive plant species. Of these, the highest biovolume-producing plants (fanwort and variable-leaf milfoil) are likely to present the biggest management concerns going forward.

TRC is also aware of other management concerns, such as waterborne pathogens, that may impact primary recreation (swimming), although it was beyond the scope of this study to assess levels or sources of those pollutants.

A number of actions could potentially be considered for implementation at Lake Massapoag to address or track these management issues. Those that would clearly benefit the lake based on observations to date are presented in the following section. However, given the limited scope of this study, additional data collection and analysis, as well as further consultation with Town officials and partners (e.g., Neponset River Watershed Association), would be recommended to fully develop a comprehensive assessment report and management plan for Lake Massapoag.

Next Steps

Based on the data gathered under the field assessment as well as the TRC's current understanding of the Town's goals, our recommendations for next steps consist of the following key elements:

- ***Continue to implement measures to control aquatic invasive species.***
    - The Town has used herbicides (fluridone – trade name Sonar), hand harvesting, and DASH to manage aquatic invasive species in Lake Massapoag.
    - Given the extent and species composition of aquatic plant growth in the Lagoon, TRC recommends using fluridone as the primary management tool there in 2023. The Lagoon harbors the largest reservoir of invasive fanwort in the system and will continue to supply Lake Massapoag with fragments until the infestation is effectively brought under control. A well-applied fluridone treatment could substantially reduce this source to the broader lake. TRC understands that the application of fluridone to the Lagoon may require use of a barrier to maintain the concentration and prevent release into areas where fluridone could potentially impact a state-listed plant species.

      Fluridone could also be used to treat fanwort beds growing in the South Cove. However, this would require lake lowering to prevent impacts to the state-listed plant species. Additionally, given the long contact time required for fluridone (45 days or more), the area treated would need to be much larger than the actual area of the plant beds to counter dilution. While slow-release pelleted formulations may be able to help extend the effective period of treatment, some booster treatments will likely also be required. This adds to the cost of treatment.

- DASH offers an excellent means of fanwort and variable-leaf milfoil control in the South Cove, if budget allows and fluridone treatment is not pursued for this area. If budget is insufficient to harvest all of the plants, TRC recommends focusing on containment of the primary beds to prevent further spread.
- Selective hand harvesting (using divers as needed) may be used in extremely shallow areas (e.g., Fletcher's Cove) to address regrowth of the two target species. This approach is also appropriate to sparse outlying beds of the target species or as a means to control pioneer infestations of new invasive species (should they be found) elsewhere in the lake.

- ***Develop a watershed-based plan to address existing water quality issues and help prevent future problems from developing.***
  - A variety of in-lake and watershed options are available to address existing water quality management issues, including low dissolved oxygen as well as excessive levels of phosphorus and other pollutants. The approach taken to managing water quality at Lake Massapoag may involve multiple options to provide the desired level of improvement. This plan would evaluate each of the applicable options and detail the advantages and limitations to implementation.
  - Developing this plan will allow the Town to identify, prioritize, and budget for specific water quality improvement actions over a multi-year basis. It will also help to identify potential sources of funding for design, permitting, and implementation.
  - The Town recently submitted an application for watershed assessment funding available through Section 604(b) of the Clean Water Act. If funded, the Town anticipates being able to complete a watershed-based plan and submit it for approval to MassDEP. This would allow the Town to then pursue additional funding for project design, permitting, and implementation available through Section 319 of the Clean Water Act or other sources.
- ***Investigate sediments as a potentially significant internal source of phosphorus loading to Lake Massapoag.***
  - The calculation of phosphorus release rates was beyond the scope of this study. However, based on the concentration of iron-bound and loosely sorbed phosphorus in the single grab sample collected from the deep hole location, internal loading has the potential to be a significant source of phosphorus to the water column. Therefore, the assessment of phosphorus release rates in the context of a broader nutrient budget for Lake Massapoag is recommended.
  - A more robust sediment sampling program could include additional grab samples or cores. The advantage of coring is that it allows vertical profiles of phosphorus fractions to be constructed from analysis of discrete sediment cross sections. This can be used to delineate the depth of the active release zone in sediments, which could be an important piece of information for designing an optimized phosphorus inactivation approach (e.g., alum treatment). However, either approach will provide more confidence as to whether high release rates are likely to be isolated or widespread across a broader area of the pond.
  - TRC recommends collection and analysis of sediment from at least four additional locations in the lake to determine the extent of potential high-release sediments. The cost of vertical cores is often several times higher than grab samples, primarily because it involves analysis of multiple cross section slices from each core.

- ***Develop and implement an annual monitoring program for Lake Massapoag.***
    - TRC recommends that the Town continue to implement monitoring of water quality and aquatic plants in Lake Massapoag. Developing and funding an ongoing monitoring program will help ensure that conditions in the lake are tracked and will provide critical data for evaluating the effectiveness of any management actions implemented in the future.
    - Should new management actions be implemented to address water quality, sediment quality, or aquatic plant growth at Lake Massapoag, additional monitoring would be recommended to evaluate the efficacy of each of the specific elements of the management program.

      However, in the absence of active management, TRC recommends the following monitoring program components to measure ambient conditions and track trends.

        - Periodic field visits to collect and analyze water quality and phytoplankton samples. These visits would test for important analytes that may not be readily measured through a continuous water quality data collection system.

          For the coming year, TRC recommends that the Town at least maintain the level of monitoring completed in 2022. If funding priorities require, some of the analytes monitored in 2022 could be removed from the 2023 monitoring program or the quantity could be reduced to save cost. These include the following:

            - Total dissolved phosphorus
            - Nitrite-nitrogen
            - Iron

          Additionally, the Town could consider reducing the number of locations where in-lake water quality samples are collected. The deep hole location provides the most value for tracking the overall water quality condition in the lake, especially during the months when the lake is thermally stratified. Fewer consistent patterns in water quality were observed among the various cove sampling locations in 2022. However, these locations may still hold value for source identification or simply quantifying variability in lake water quality.
        - Annual or biannual mapping of aquatic plant extent and density with a focus on nuisance species. This can help identify new infestations and address them before they become widespread and more costly to manage. If mapping is completed prior to and following implementation of management actions, it can be used to evaluate the effectiveness of those specific actions.
        - Annual monitoring report to provide a summary and interpretation of observed conditions and recommended adjustments to lake monitoring and management for the following year.

References

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Redfield, A. C. 1958. The biological control of chemical factors in the environment. *American Scientist*, 46: 205–221.

Wagner, K. J., D. Meringolo, D. F. Mitchell, E. Moran, and S. Smith. 2017. Aluminum treatments to control internal phosphorus loading in lakes on Cape Cod, Massachusetts. *Lake and Reservoir Management*, 33(2): 171-186.

It has been a pleasure working with your team in 2022 to document the baseline condition of Lake Massapoag and better understand the management challenges it faces. We look forward to the opportunity to assist you in the future.

Please do not hesitate to contact me with any questions.

Sincerely,

TRC ENVIRONMENTAL CORPORATION

Matt Ladewig, CLM
Project Director