

Annual Report

2020 Post-Treatment Management Program
Westford Ponds – Keyes, Long Sought For, Nabnasset
Westford, MA

Prepared by: SÖLitude Lake Management
590 Lake Street
Shrewsbury, MA 01545

Prepared for: Town of Westford
c/o Carol Gumbart, Rae Dick
55 Main Street
Westford, MA 01886

Submitted on: December 1, 2020

Introduction

In accordance with the aquatic management program contract between SÖLitude Lake Management and the Town of Westford for Keyes Pond, Long Sought For Pond, and Nabnasset Pond, the following document serves to provide this year's treatment and monitoring results, as well as recommendations for the 2021 management season. As proposed, ESS Group, Inc. (ESS) conducted all monitoring work.

All management activities were conducted in compliance with the current Orders of Conditions issued by the Westford Conservation Commission and the Licenses to Apply Chemicals (#WM04-0000143 – Keyes, WM04-0000144 – Long Sought For, WM04-0000145 - Nabnasset) issued by the MA DEP Office of Watershed Management.

Consistent with management in previous years, the main objective of the 2020 program was to achieve control of non-native aquatic vegetation in three Westford ponds, specifically variable watermilfoil (*Myriophyllum heterophyllum*), curlyleaf pondweed (*Potamogeton crispus*), and Eurasian watermilfoil (*Myriophyllum spicatum*) in their respective locations, as well as manage any nuisance algae growth.

Herbicide Treatments

Treatment of Long Sought For Pond and Nabnasset Pond were performed on June 18 to control respective aquatic invasive species growth around select areas of the shoreline. Prior to both treatment events, notification was posted on the Town's website and Facebook page, as well as water-use restriction signs that were posted along the shoreline of each pond.

All three ponds were treated utilizing diquat herbicide; approximately 30 acres in Long Sought For, and 30 acres in Nabnasset were treated.

Nabnasset and Keyes were also treated with copper sulfate to mitigate algal blooms at later dates (Nabnasset - July 3, August 10; Keyes - August 18).



Post-Treatment Assessment

The final post-treatment plant mapping and WQ sampling at all three ponds was conducted by ESS in early October.

Overall, the herbicide treatments at each of the ponds was successful in controlling the target species present. ESS did not observe any variable watermilfoil in Keyes Pond during the post-treatment mapping. Nabnasset Lake did not have any curlyleaf pondweed growth present at the time of the survey but had variable milfoil still in Shipley Swamp. Although curlyleaf pondweed was not observed in Long Sought For Pond, there was an expansion of flat-stem pondweed from the spring survey efforts. This species was an additional target in this year's treatment efforts as the growth, along with curlyleaf pondweed at the time, had overrun the entire littoral zone. Overall, all three ponds continued to maintain a diverse and significant native aquatic plant community post-treatment events. The detailed results of the sampling and post-treatment mapping work are included in the attached report by ESS; the other four Westford Ponds were also surveyed this fall and are included in the same report.

Ongoing Management Recommendations

Consistent with prior years, we recommend continuing annual monitoring and treatment, if warranted, at each pond in 2021. We strongly recommend initiating monitoring and management of all ponds in early spring to sufficiently allow for scheduling and appropriate treatment timing for the various target species. This year's differently timed surveying based on target species worked well. For monitoring, ESS recommends early season vegetation mapping, water quality sampling, as well as the required permit compliance monitoring to correspond with what has been done this and in previous years. More information on the recommendations from ESS are included in their attached report.

Regarding vegetation management, we anticipate regrowth of variable watermilfoil and curlyleaf pondweed in each of the ponds where it was observed this season. Treatment of these ponds should be considered using diquat herbicide again as it has proven to be effective in controlling the target species there. Due to the significant increase in flat-stem pondweed observed at Long Sought For Pond by residents this season, we recommend diligently monitoring the pond for growth through the season and conducting a diquat treatment, if necessary, to continue to manage the growth. For all of the ponds that were not managed this season, we recommend continuing diligent monitoring at each to be aware of any shifts in vegetation compositions and/or new invasive species infestations. Of the unmanaged ponds this year, if the Town wants to begin managing any of them in 2021 or future years, we are happy to provide management recommendations and strategies as necessary to align with the Town's goals and budget.

November 3, 2020

Kara Sliwoski
SOLitude Lake Management
590 Lake Street
Shrewsbury, Massachusetts 01545

**Re: *Lake and Pond Monitoring and Reporting, Post-treatment/ Late Season – 2020
Westford, Massachusetts
ESS Project No. S469-005***

Dear Ms. Sliwoski,

ESS Group, Inc. (ESS) was contracted by SOLitude Lake Management (SOLitude) to complete a post-treatment monitoring program at three lakes and ponds located within the Town of Westford (Town), as follows: Keyes Pond, Long Sought-for Pond, and Nabnasset Lake. In addition, a late season monitoring event was completed at four additional ponds, as follows: Old Mill/Graniteville Ponds, Burge's Pond, Kennedy Pond, and Forge Pond. The post-treatment/late season monitoring program was completed to complement pre-treatment/early season monitoring conducted by ESS in late spring 2020.

This report provides the findings of the monitoring program, builds on the findings of prior monitoring efforts, and makes recommendations for management of these water bodies in 2021.

Post-treatment and Late-Season Monitoring 2020

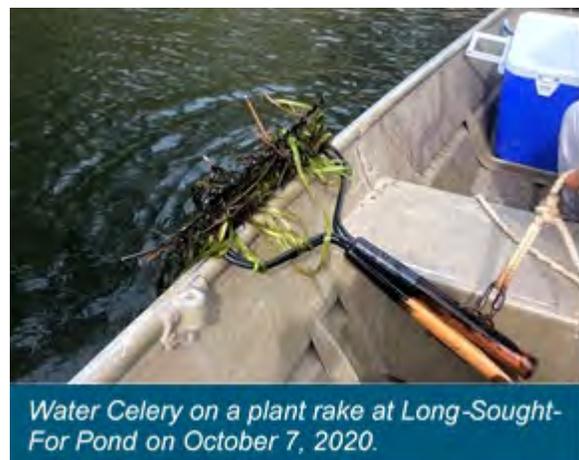
The 2020 post-treatment/late season monitoring program consisted of aquatic vegetation mapping and water quality sampling and was completed at each of the seven ponds on the following dates:

- October 7 (Late season mapping of Nabnasset Lake and Long Sought-for Pond)
- October 8 (Post-treatment mapping of and Keyes Pond, Burge's Pond, and Kennedy Pond)
- October 15 (Late season mapping of Forge Pond and Old Mill/Graniteville)

Aquatic Vegetation Monitoring

Aquatic plants were surveyed using comparable methods to recent monitoring events, including the 2020 pre-treatment/early season monitoring effort. Plant rakes were used to help assess aquatic invasive plant densities. Data were collected using a combination of field notes and a Trimble Geo7x DGPS receiver capable of sub-meter accuracy. Aquatic plants observed during the post-treatment/ late season monitoring are presented in Table 1.

Additional details on the results of the aquatic plant surveys are presented, by pond, on subsequent pages.



Water Celery on a plant rake at Long-Sought-For Pond on October 7, 2020.

Table 1. Aquatic Plants Observed at Westford Ponds during 2020 Post-treatment/ Late Season Surveys

Common Name	Scientific Name	Native or Exotic	Keyes Pond	Long Sought-for Pond	Nabnasset Lake	Old Mill/Graniteville Ponds	Burge' s Pond	Kennedy Pond	Forge Pond
Canadian Waterweed	<i>Elodea canadensis</i>	Native				X			X
Clasping-leaf Pondweed	<i>Potamogeton perfoliatus</i>	Native						X	
Common Bladderwort	<i>Utricularia macrorhiza</i>	Native	X	X	X				X
Coontail	<i>Ceratophyllum demersum</i>	Native				X			
Curly-leaf Pondweed	<i>Potamogeton crispus</i>	Exotic							X
Duckweed	<i>Lemna sp.</i>	Native				X			
Eurasian Milfoil	<i>Myriophyllum spicatum</i>	Exotic							X
Fanwort	<i>Cabomba caroliniana</i>	Exotic				X			X
Flat-leaf Bladderwort	<i>Utricularia intermedia</i>	Native	X						
Flat-stem Pondweed	<i>Potamogeton zosteriformis</i>	Native		X					
Floating-leaf Pondweed	<i>Potamogeton epihydrus</i>	Native	X	X					
Golden Hedge-hyssop	<i>Gratiola aurea</i>	Native						X	
Little Floating Bladderwort	<i>Utricularia radiata</i>	Native					X		
Low Milfoil	<i>Myriophyllum humile</i>	Native					X		
Muskwort	<i>Chara spp.</i>	Native						X	
Quillwort	<i>Isoetes spp.</i>	Native						X	
Robbins' Pondweed	<i>Potamogeton robbinsii</i>	Native							X
Spikerush	<i>Eleocharis sp.</i>	Native		X			X		
Southern Naiad	<i>Najas guadalupensis</i>	Native		X	X				
Variable-leaf Milfoil	<i>Myriophyllum heterophyllum</i>	Exotic			X	X			X
Water Celery (Tapegrass)	<i>Vallisneria americana</i>	Native		X	X				X
Watershield	<i>Brasenia schreberi</i>	Native			X		X	X	X
White Water Lily	<i>Nymphaea odorata</i>	Native	X	X	X	X	X		X
Yellow Water Lily	<i>Nuphar lutea variegata</i>	Native			X	X	X		X
Total			4	7	7	7	6	5	11

Keyes Pond

Four species of native plants were observed in Keyes pond during the 2020 post-treatment survey. Aquatic invasive Curly-leaf pondweed (*Potamogeton crispus*), which covered approximately 0.8 acre in a cove in the southeastern region of the pond during pre-treatment monitoring, was not observed during post-treatment monitoring (Figure 1). Invasive variable-leaf milfoil (*Myriophyllum heterophyllum*) was not observed during pre- or post-treatment mapping efforts in 2020, which is consistent with results of the 2018 and 2019 post-treatment surveys.



Dense patches of native white water lily were observed at Keyes Pond on October 8, 2020.

Long Sought-for Pond

Six species of aquatic plants were observed in Long Sought-for Pond during the 2020 post-treatment survey. Though floating stem fragments of curly-leaf pondweed were observed during the 2020 pre-treatment survey, no exotic plants were observed during the post-treatment mapping.

Sparse to very dense patches of native flat-stem pondweed (*Potamogeton zosteriformis*) were observed covering approximately 24.3 acres along both the northern and southern shorelines during the 2020 post-treatment mapping (Figure 2). This represents an expansion compared to the 2020 pre-treatment mapping, when flat-stem pondweed beds covered 9.3 acres of the pond, and were largely confined to northern shoreline areas. During the post-treatment survey, plants throughout the pond were in decline, which leaves open the possibility that beds of this species were even denser or more extensive at some point over the summer.

Nabnasset Lake

Seven species of aquatic plants were observed at Nabnasset Lake during the 2020 post-treatment survey, including one exotic invasive species. Invasive variable-leaf milfoil (*Myriophyllum heterophyllum*) was observed in Shipley Swamp during the 2020 pre-treatment mapping, and was reported by a homeowner prior to the post-treatment mapping. The presence of this species in the swamp was again confirmed by ESS during the 2020 post-treatment mapping (Figure 3). Aquatic invasive curly-leaf pondweed was present in dense patches during the 2020 pre-treatment survey, but was not observed during the post-treatment survey.

Native water celery (*Vallisneria americana*) was observed growing in sparse to very dense beds along much of the shoreline of Nabnasset Lake during the 2020 late season survey (Figure 3). This species covered approximately 29.9 acres, with densest growth occurring along the shoreline and within the cove located in the southeastern portion of the lake, and along a portion of the northern shore.

Old Mill/Graniteville Ponds

Six species of aquatic plants were observed at the Old Mill/Graniteville Ponds during the 2020 late season survey, including two exotic invasive species. Aquatic invasive fanwort (*Cabomba caroliniana*), and variable-leaf milfoil were observed during the late season mapping.

Fanwort was found growing in sparse to dense stands covering 6.1 acres in both basins of the pond during the 2020 late season survey (Figure 4). This represents a very slight decrease in overall fanwort extent, compared to the 6.3 acres of growth reported during the early season survey.

Variable-leaf milfoil was observed growing in sparse to patchy growth in both basins of the Old Mill/Graniteville Ponds during the 2020 late season survey (Figure 5). Cover of this species notably decreased from 4.3 acres during the 2020 early season survey to approximately 0.8 acres during the late season survey.

Burge's Pond

Six species of aquatic plants were found in Burge's Pond during the 2020 late season survey. No aquatic invasive plant species were observed in Burge's Pond during the early or late season surveys in 2020 (Figure 6). Based on these survey results, the control of variable-leaf milfoil previously achieved in 2016 appears to have persisted.

Kennedy Pond

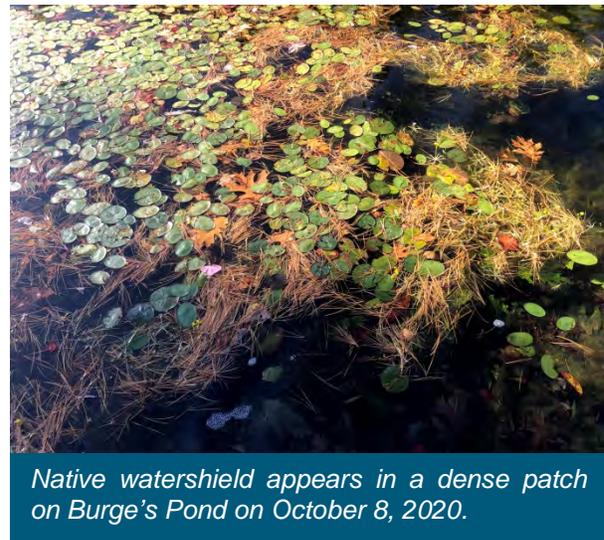
Five species of aquatic plants were observed in Kennedy Pond during the late season survey. No aquatic invasive plant species were found within Kennedy Pond during the 2020 early or late season surveys (Figure 7). However, as in prior years, the exotic invasive common reed (*Phragmites australis*) was observed growing along portions of the shoreline.

Forge Pond

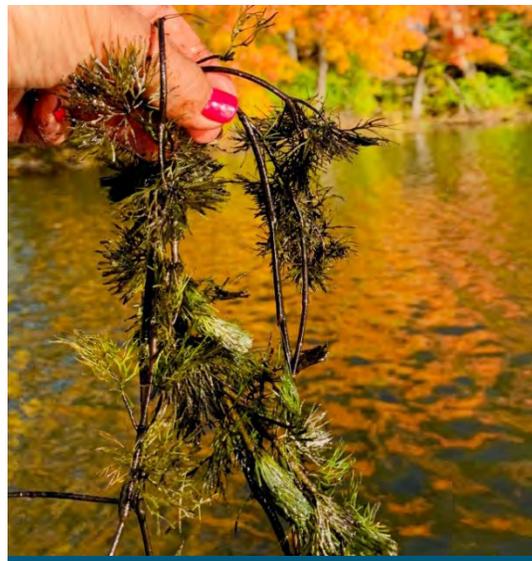
Nine species of aquatic plants were observed during the late season survey of Forge Pond, including four exotic invasive species. The following exotic invasive species were observed during both the pre and post treatment mapping: curly-leaf pondweed, variable-leaf milfoil, Eurasian milfoil, and fanwort.

Curly-leaf pondweed cover in Forge Pond increased by approximately 1.7 acres between the 2020 early and late season surveys. During the late season survey, curly-leaf pondweed was present in sparse patches covering a total of 3.3 acres, and a single very dense 0.5-acre patch (Figure 8). Curly-leaf pondweed growth was primarily located in shallow shoreline areas.

Fanwort was present in sparse beds covering approximately 3.5 acres, and in a single dense bed covering approximately 0.8 acres, during the 2020 late season survey (Figure 9). As only 0.5 acres of fanwort growth was observed during the early season survey, this



Native watershield appears in a dense patch on Burge's Pond on October 8, 2020.



Sprig of fanwort observed at Forge Pond on October 15, 2020.

species exhibited a notable expansion in Forge Pond during 2020.

Variable-leaf milfoil covered approximately 6.8 acres in sparse to patchy growth along shoreline areas of Forge Pond during the 2020 late season survey (Figure 10). This represents an increase in extent compared to the approximately 3.4 acres of variable-leaf milfoil growth present during the early season survey.

Eurasian milfoil was observed in sparse patches covering approximately 3.9 acres of Forge Pond during the 2020 late season survey (Figure 11). Some slight changes in density and distribution between the 2020 early and late season surveys were noted; total Eurasian milfoil cover increased by approximately 0.4 acres.

Water Quality Monitoring

As in 2019 and the 2020 pre-treatment/early season monitoring event, ESS conducted water quality sampling at three stations within each waterbody, including at least one location in the deepest portion of each waterbody. During the water quality monitoring event, ESS measured the following parameters in the field: dissolved oxygen, temperature, turbidity, pH, and water clarity (Secchi disk). ESS also collected water samples for laboratory analysis of the following analytes: hardness, nitrate nitrogen, alkalinity, total phosphorus, total Kjeldahl nitrogen, and ammonia nitrogen. Notable water quality results are summarized in the following sections.

Dissolved Oxygen

Each waterbody except Keyes Pond exhibited dissolved oxygen concentrations suitable for aquatic life near the surface. Dissolved oxygen conditions at both the deep hole and inlet of Keyes Pond were below the state numerical criterion of 5.0 mg/L for warmwater fisheries. Post-treatment/late season water quality results indicate low (hypoxia) to very low (anoxia) dissolved oxygen levels in the deeper waters of all the ponds sampled. This pattern was most extensive in Keyes Pond, Old Mill/Graniteville Ponds, Long-Sought-for Pond, and Forge Pond. Extensive areas of persistently low dissolved oxygen concentrations are typically considered unsupportive of most aquatic life. Additionally, they may increase the likelihood of internal phosphorus release from pond sediments, which can compound management issues associated with eutrophication (nutrient enrichment).

Turbidity

Turbidity varied somewhat within each of the water bodies but did not appear to be abnormally elevated in any of the locations sampled during post-treatment/late season monitoring. Mostly minor variations were observed among sampling locations within a pond and between waterbodies.

Secchi Depth (Transparency)

Secchi depth is a measure of water transparency and may be reduced by suspended sediments, algal growth, or the presence of other organic matter in the water column. Reduced Secchi depths are typically associated with nutrient-enriched ponds. During post-treatment/late season monitoring, the shallowest Secchi depths were measured at Old Mill/Graniteville Ponds and Forge Pond, where water transparency extended only 1.5 and 1.75 meters, respectively. The deepest Secchi depths (i.e., clearest water) were measured at Burge's Pond, where transparency extended to 4.0 meters.

pH, Hardness, and Alkalinity

In alignment with pre-treatment/early season sampling, most of the locations sampled during post-treatment/late season monitoring were circumneutral (i.e., pH near 7.0). The most acidic pH was

measured in Burges Pond, and the most basic pH measurements were collected in Long-Sought-for Pond and Nabnasset Lake.

Hardness and alkalinity tend to be naturally higher in the Merrimack River valley than adjacent parts of eastern Massachusetts, although they can also be influenced by human activity in the watershed as well as atmospheric acid deposition. These parameters varied substantially between ponds, but generally demonstrated similar patterns in variation with lower hardness values corresponding to lower alkalinity. This is not unexpected, as harder waters tend to have a higher alkalinity (also known as acid neutralizing capacity). Increased alkalinity suggests greater buffering capacity of the water (i.e., resistance to pH change). Ponds with low buffering capacity may be susceptible to more abrupt swings in pH than those with higher alkalinity.

Phosphorus and Nitrogen

Phosphorus and nitrogen are both major nutrients fueling plant and algal growth. Of the two, phosphorus tends to be limiting nutrient in most New England freshwater systems. However, nitrogen levels can also impact the overall productivity of the system and type of algal growth favored, and may even influence the production of toxins in some cyanobacteria. In general, high nutrient levels in the water column can contribute to algal blooms and excessive floating plant growth. High availability of nutrients in the sediments can contribute to excessive rooted plant growth.

During post-treatment/late season monitoring, total phosphorus concentrations were generally highest at Keyes Pond and Old Mill/ Graniteville Ponds. Algal blooms may occur even where total phosphorus levels are very low. However, they tend to be more frequent and are more likely to become problematic where concentrations regularly exceed 0.020 mg/L. Sediment release of phosphorus is apparent when bottom (hypolimnetic) concentrations are much higher than surface (epilimnetic) concentrations during the time of the year when the water body is stratified (warm surface water overlaying cold bottom water). This pattern is most apparent at Old Mill/Graniteville Ponds, Long-Sought-for Pond, and Nabnasset Lake. As indicated previously, release of sediment phosphorus may be aggravated by low dissolved oxygen concentrations at depth.

Overall nitrogen levels were highest at Keyes Pond, and nitrate nitrogen levels were greatest at Nabnasset Lake. High levels of nitrate nitrogen may be an indication of septic loading or stormwater runoff. Post-treatment/late season samples from Nabnasset Lake and Long Sought-for Pond contained the highest levels of ammonia nitrogen, which may be associated with direct septic loading or persistent anoxic or hypoxic conditions.



Table 2. Dissolved Oxygen Profiles at Deep Hole Locations during 2020 Post-treatment/Late Season Monitoring

Depth	Keyes Pond		Old Mill/Graniteville Ponds		Burge's Pond		Kennedy Pond		Long Sought-for Pond		Nabnasset Lake		Forge Pond	
	m	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	
0.5	41.60	4.04	72.70	7.30	66.70	6.44	48.90	5.72	73.90	6.83	71.90	6.74	74.20	7.44
1.0	40.70	3.94	67.20	6.65	66.90	6.47	49.00	5.77	74.40	6.90	70.60	6.63	72.70	7.25
1.5	40.80	3.96	70.50	7.20	66.70	6.45	50.90	5.75	74.30	6.92	69.80	6.55	72.50	7.22
2.0	41.00	3.97	67.90	6.80	67.00	6.49	53.10	5.74	75.50	7.04	69.90	6.52	73.60	7.37
2.5	41.00	3.98	38.80	4.01	67.20	6.50	54.00	5.76	75.60	7.07	70.10	6.56	73.50	7.34
3.0	41.10	3.99	34.60	3.59	67.10	6.48	54.90	5.65	75.50	7.08	70.00	6.54	71.80	7.17
3.5	40.80	3.97	35.70	3.86	67.40	6.52	55.60	5.62	75.80	7.11	70.40	6.59	71.90	7.12
4.0	41.10	3.99	31.30	3.38	67.20	6.50	56.00	5.67	75.80	7.11	70.70	6.60	71.20	7.11
4.5	40.80	3.98					56.50	5.63	75.20	7.07	71.20	6.67	69.20	7.86
5.0							57.30	5.63	75.20	7.07	71.00	6.64	66.70	6.65
5.5							57.90	5.65	74.60	7.02	71.30	6.66	67.10	6.71
6.0							58.20	5.59	74.80	7.02	71.20	6.66	67.40	6.73
6.5							58.70	5.63	68.90	6.50	71.30	6.66	66.20	6.62
7.0							59.20	5.68	43.60	4.38	70.20	6.58	0.70	0.06
7.5									29.80	2.85				
Total depth (m)	5.7		4.4		5.3		7.2		7.7		7.5		7.4	

Table 3. Temperature Profiles at Deep Hole Locations during 2020 Post-treatment/Late Season Monitoring

Depth (m)	Keyes Pond	Old Mill/Graniteville Ponds	Burge' s Pond	Kennedy Pond	Long-Sought-for Pond	Nabnasset Lake	Forge Pond
0.5	16.5	14.8	16.6	17.2	18.1	17.9	15.3
1.0	16.4	14.5	16.6	17.1	18.0	17.9	15.2
1.5	16.4	14.4	16.6	17.0	17.8	17.9	15.2
2.0	16.4	14.5	16.6	17.0	17.7	17.9	15.2
2.5	16.4	12.6	16.6	17.0	17.6	17.9	15.2
3.0	16.4	12.4	16.5	17.0	17.6	17.9	15.2
3.5	16.4	12.3	16.5	17.0	17.6	17.8	15.2
4.0	16.4	12.2	16.5	16.9	17.5	17.8	15.1
4.5	16.4			16.9	17.5	17.8	15.1
5.0				16.9	17.5	17.8	15.1
5.5				16.9	17.5	17.8	15.1
6.0				16.9	17.4	17.8	15.0
6.5				16.9	17.4	17.8	15.0
7.0				16.9	17.1	17.8	15.0
7.5					17.0		
Total depth (m)	5.7	4.4	5.3	7.2	7.7	7.5	7.4

Table 4. Water Quality Parameters Collected During 2020 Post-treatment/Late Season Monitoring

Parameter	Units	Keyes Pond			Old Mill/Graniteville Ponds			Burge's Pond			Kennedy Pond			Long Sought-for Pond			Nabnasset Lake			Forge Pond			
		Station ID	KEY-A	KEY-B	KEY-C	OLD-A	OLD-B	OLD-C	BUR-A	BUR-B	BUR-C	KEN-A	KEN-B	KEN-C	LSF-A	LSF-B	LSF-C	NAB-A	NAB-B	NAB-C	FOR-A	FOR-B	FOR-C
		Location	Deep hole mid-depth	Inlet	Outlet	Deep Hole		Inlet	Deep Hole		In-pond	Deep Hole		In-pond	Deep Hole		Inlet	Deep Hole		Outlet	Deep Hole		Inlet
					Surface	Bottom		Surface	Bottom		Surface	Bottom		Surface	Bottom		Surface	Bottom		Surface	Bottom		
Total depth	m	5.7	1.0	0.5	4.4		1.5	5.3		2.3	7.2		0.8	7.7		0.3	7.5		2.0	7.4		1.0	
Sample depth	m	3.0	0.5	surface	2.0	0.5	0.5	0.5	4.0	0.5	0.5	6.5	0.5	0.5	6.0	surface	0.5	6.0	0.5	0.5	6.5	0.5	
Temperature	C	16.5	16.9	16.4	14.8	14.3	15.7	16.6	16.5	16.4	17.2	16.9	15.6	18.1	17.4	18.7	17.9	17.8	17.7	15.3	15.0	15.6	
Dissolved oxygen	%	41.6	49.8	57.4	72.7	7.3	9.8	66.7	67.2	64.8	48.9	58.7	7.2	73.9	74.8	71.3	71.9	71.2	57.8	74.2	66.2	80.4	
	mg/L	4.04	4.88	5.22	7.30	NS	NS	6.44	6.50	6.29	5.72	5.63	7.35	6.83	7.02	6.52	6.74	6.66	5.46	7.44	6.62	-	
Turbidity	NTU	2.53	2.08	1.62	3.37	3.76	3.62	1.25	1.38	1.95	1.49	1.71	1.29	1.70	1.61	1.83	1.41	1.48	0.35	3.36	3.28	2.95	
pH	SU	6.82	7.23	6.93	7.38	7.14	7.31	6.23	5.97	6.73	6.69	6.92	7.10	7.39	7.36	7.42	7.23	7.25	7.60	6.44	7.11	7.30	
Secchi Depth	m	-	bottom (1.0)	bottom (0.5)	1.5		bottom (1.5)	4.0		2.50	3.5		bottom (0.75)	3.3		bottom (0.3)	2.5		bottom (2.0)	1.8		1.9	
Hardness	mg/L	38.3	35.6	36.1	80.9	81.7	76.4	1.6	1.6	1.6	39.9	38.9	39.8	45.4	43.4	43.4	57.1	58.7	60.1	78.4	77.8	77.7	
Alkalinity	mg/L	25.2	25.0	23.2	50.7	50.7	47.4	<5.0	<5.0	<5.0	17.9	17.1	17.2	28.5	27.7	27.6	36.9	33.4	32.8	47.9	46.7	46.3	
Total phosphorus	mg/L	0.043	0.049	0.034	0.027	0.034	0.036	0.035	0.032	0.021	0.018	0.023	0.025	0.030	0.019	0.022	0.024	0.032	0.022	0.027	0.022	0.018	
Nitrate nitrogen	mg/L	<0.02	<0.02	<0.02	0.06	0.06	0.06	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	0.14	0.14	0.12	0.03	0.03	0.03	
Total Kjeldahl nitrogen	mg/L	0.63	0.67	0.55	0.55	0.60	0.50	0.49	0.48	0.41	0.40	0.39	0.36	0.52	0.75	0.90	0.49	0.54	0.98	0.68	0.55	0.55	
Ammonia nitrogen	mg/L	0.14	0.12	<0.05	0.13	0.12	0.05	<0.5	0.09	0.07	<0.05	0.07	<0.5	0.09	0.18	0.26	0.20	0.23	0.41	0.14	0.13	0.12	

Management Recommendations for 2021

The vegetation management program at Keyes Pond, Long Sought-for Pond, and Nabnasset Lake continues to be successful in controlling most of the targeted perennial exotic species (including exotic milfoils). In fact, ESS did not observe any exotic milfoils in Keyes or Long Sought-for Pond in 2020. Although variable-leaf milfoil was observed at Nabnasset Lake, it remains confined to Shipley Swamp and does not yet appear to have established an active bed in the lake proper. However, variable-leaf milfoil should be closely monitored for regrowth in Nabnasset Lake, as it has become more common in Shipley Swamp and could re-establish in Nabnasset Lake from vegetative fragments.

Curly-leaf pondweed, which has an annual life cycle, continues to be a challenge in these ponds and requires a sustained effort over many years to successfully control (although eradication is often not realistic). This plant is typically problematic from spring through early summer and management efforts are usually targeted for this period to prevent plant maturation and the release of seeds and turions. However, curly-leaf pondweed occasionally reaches nuisance levels later in the year, and can persist locally into late-summer. Therefore, ESS continues to recommend that the timing of management actions for curly-leaf pondweed remain flexible, where possible, to account for this possibility.

Old Mill/ Graniteville Ponds and Forge Pond were not treated in 2020. As such, both ponds continue to host large beds of exotic milfoils, curly-leaf pondweed, and fanwort. However, Forge Pond was subjected to a winter drawdown during winter 2019-2020. Despite the warm winter, it appears that the drawdown may have resulted in some control of the exotic milfoils and fanwort in the shallower portions of Forge Pond. This is reflected in the target species bed footprints, which receded somewhat from the pond shoreline, as well as the reduced density of many of the beds compared to 2019. In contrast, Old Mill/ Graniteville Ponds continue to host these species at high densities and over large extents. Due to a combination of excessive vegetative growth and low water levels, many portions of the Old Mill/ Graniteville upper basin were not navigable in 2020.

No aquatic invasive species were observed by ESS in either Burge's or Kennedy Ponds in 2020. Prior reports of variable-leaf milfoil from 2019 could not be confirmed this year in Burge's Pond. However, other native species of milfoil are present in Burge's Pond and do not currently appear to grow at nuisance levels.

Recommendations for the 2020 management program at the Westford Ponds are presented in the following sections.

Chemical Controls

The Order of Conditions issued by the Town Conservation Commission for Keyes Pond, Old Mill/Graniteville Ponds, and Burge's Pond allows herbicide treatment with fluridone (trade name Sonar) and diquat dibromide (also known as Reward, Tribune, or simply Diquat). Similarly, Long Sought-for Pond's Order of Conditions allows for treatment of aquatic vegetation with fluridone and diquat dibromide. Nabnasset Lake's Order of Conditions permits treatment of aquatic vegetation with diquat dibromide and a copper-based herbicide sold under the trade name Nautique. ESS is not aware of other herbicides currently authorized for use in any of the seven ponds included in this study.

Diquat dibromide (diquat) is recommended for the control of curly-leaf pondweed at Keyes Pond, Long Sought-for Pond, and Nabnasset Lake. Although infestations of curly-leaf pondweed appeared to be somewhat reduced in 2020, especially in Keyes Pond, they are expected to return at each pond in 2021. If possible, the timing of this treatment should be prior to the plants topping out in the water column (i.e., before June) to avoid seed and turion maturation, which would otherwise perpetuate curly-leaf pondweed growth into future years. The Town may also wish to consider the option for a second round of spot

treatments, should curly-leaf pondweed regrow later in the season, as was observed at Long Sought-for Pond and Nabnasset Lake in 2019.

Additionally, diquat may also be used for the treatment of exotic milfoils in Keyes Pond, Burge's Pond, and Nabnasset Lake should regrowth develop in 2021. If either of these milfoil species are observed in 2021, diquat (or diver harvesting, if the infestation is localized and limited in extent) could be used to manage infestations.

Finally, diquat could be effective in controlling nuisance beds of native thinleaf pondweeds, should they return to Long Sought-for Pond in 2021. If not permitted under the current Order of Conditions, an amendment may be required to allow the use of diquat for the control of native aquatic plants that occur at nuisance levels.

Fluridone is not currently recommended for use in 2021, as each of the actively managed lakes and ponds included in this report lack widespread beds of the target species that would be impacted by fluridone (e.g. fanwort and Eurasian milfoil).

Should the Town elect to move forward with active management of Old Mill/ Graniteville Ponds and/or Forge Pond, fluridone may be an appropriate chemical control for fanwort and exotic milfoils in those water bodies. Fluridone requires a long contact time to be effective on most target species and should therefore ideally be applied starting in spring. Old Mill/ Graniteville Ponds also proved to be a challenge to treat with fluridone in the past, due to the high rate of flushing through the system, particularly in the upper basin. Therefore, any treatment there would likely require the use of a pelleted slow release formulation and/or booster treatments. Additionally, or alternatively, the Town could consider use of an effective contact herbicide (e.g., flumioxazin [Clipper]), which could be highly effective despite the rapid flushing rate. However, should the Town decide to proceed with such a treatment, flumioxazin may need to be added to the Order of Conditions.

ESS is not aware of fluridone being approved for use under a valid Order of Conditions at Forge Pond. Therefore, additional permitting may be required before moving forward with a fluridone treatment at Forge Pond, if there is interest in this approach.

Nautique was not applied in 2020, to ESS's knowledge. However, it is recommended for spot or partial-lake control of nuisance beds of water celery (tapegrass) at Nabnasset Lake. These beds appeared to have expanded in 2020, which could potentially lead to greater nuisance growth in 2021.

Other copper-based algaecide formulations (selected by contractor for effectiveness on the species present) may also be helpful for the control of nuisance algal growths or blooms in any of the ponds, should they develop in 2021. Copper-based algaecide has also occasionally been used to control excessive algal growth at Keyes Pond and Nabnasset Lake in prior years.

Depending on the actual development of plant beds and algal blooms in 2021, more than one treatment may be needed to effectively address the seasonality of different target species. The specific chemical controls currently recommended for consideration in 2021 are summarized in Table 5.

Table 5. Recommended Herbicides for Aquatic Invasive Vegetation Treatment in 2021

Herbicide	Keyes Pond	Long Sought-for Pond	Nabnasset Lake
Fluridone (Sonar)			
Diquat dibromide (Reward/Diquat)	X	X	X
Copper Ethylenediamine and Triethanolamine Complexes (Nautique)			X ^a

^aRecommended for use with diquat in controlling nuisance beds of water celery (*Vallisneria sp.*)

Water Level Controls (Drawdown)

Winter drawdown has been an effective management option for the control of variable-leaf milfoil at Nabnasset Lake in the past. However, this species was not observed in the lake during either the 2020 pre-treatment or post-treatment survey and appears to remain confined to Shipley Swamp. ESS does not believe a full six-foot drawdown would provide significant advantages for the control of exotic plants in Nabnasset Lake, and such action is not anticipated for the winter of 2020-2021. ESS is aware that a smaller shoreline maintenance drawdown may occur over the winter of 2020-2021.

Drawdown did appear to be impactful on target species at Forge Pond without resulting in significantly undesirable impacts on non-target plants. Therefore, ESS recommends another drawdown in winter 2020-2021 for the purpose of controlling shallow growths of exotic milfoils and fanwort.

Low-dose Alum

A low-dose alum treatment was approved under the original Order of Conditions for Burge’s, Keyes, and Old Mill/Graniteville Ponds (DEP File # 334-1635) and may be an option for implementation in 2021, if needed. Although ESS is unaware of any cyanobacteria or widespread nuisance algae blooms at the ponds in 2020, these have previously occurred at Keyes Pond, Old Mill/Graniteville Ponds, and Nabnasset Lake.

Prior nutrient budgets developed by ESS in 2017 suggest that low-dose alum could be effective at stripping phosphorus, algae, and particulates from incoming flows and the pond water column while also gradually reducing internal recycling of phosphorus from the sediments. Therefore, it may be useful for providing rapid improvement of water quality conditions, particularly in Keyes Pond, where low water transparency and dissolved oxygen concentrations tend to be more persistent. Alum is more expensive to apply than copper for the control of algae. However, it also targets one of the root causes of excessive algal growth and, therefore, may provide greater overall benefit.

These nutrient budgets also suggested the potential for benefits from a higher dose alum treatment at water bodies with relatively low flushing rates and higher potential for internal recycling of phosphorus from the sediments, such as Nabnasset Lake. Should the Town desire to explore the feasibility of such a treatment, additional study would need to be completed to identify the appropriate dosing, address logistical issues, and identify appropriate mitigation measures.



Monitoring

The 2020 monitoring program was useful in identifying newly emerging management issues and better measuring change at each of the ponds of interest. Therefore, ESS recommends pre-treatment/early season and post-treatment/late season water quality and aquatic vegetation monitoring at each pond in 2021, with a priority on water bodies where active management has recently been undertaken or is likely to be advanced in 2021. As always, continuing to monitor each of the ponds will allow for the detection of pioneer infestations of invasive species before they spread, thereby allow the Town the opportunity to respond quickly and avoid or minimize more costly large-scale management activities in the future.

We appreciate the opportunity to work with you on this project. Please contact Matt Ladewig at (401) 330-1204 if you have any questions.

Sincerely,

ESS GROUP, INC.

A handwritten signature in black ink that reads "Matt Ladewig".

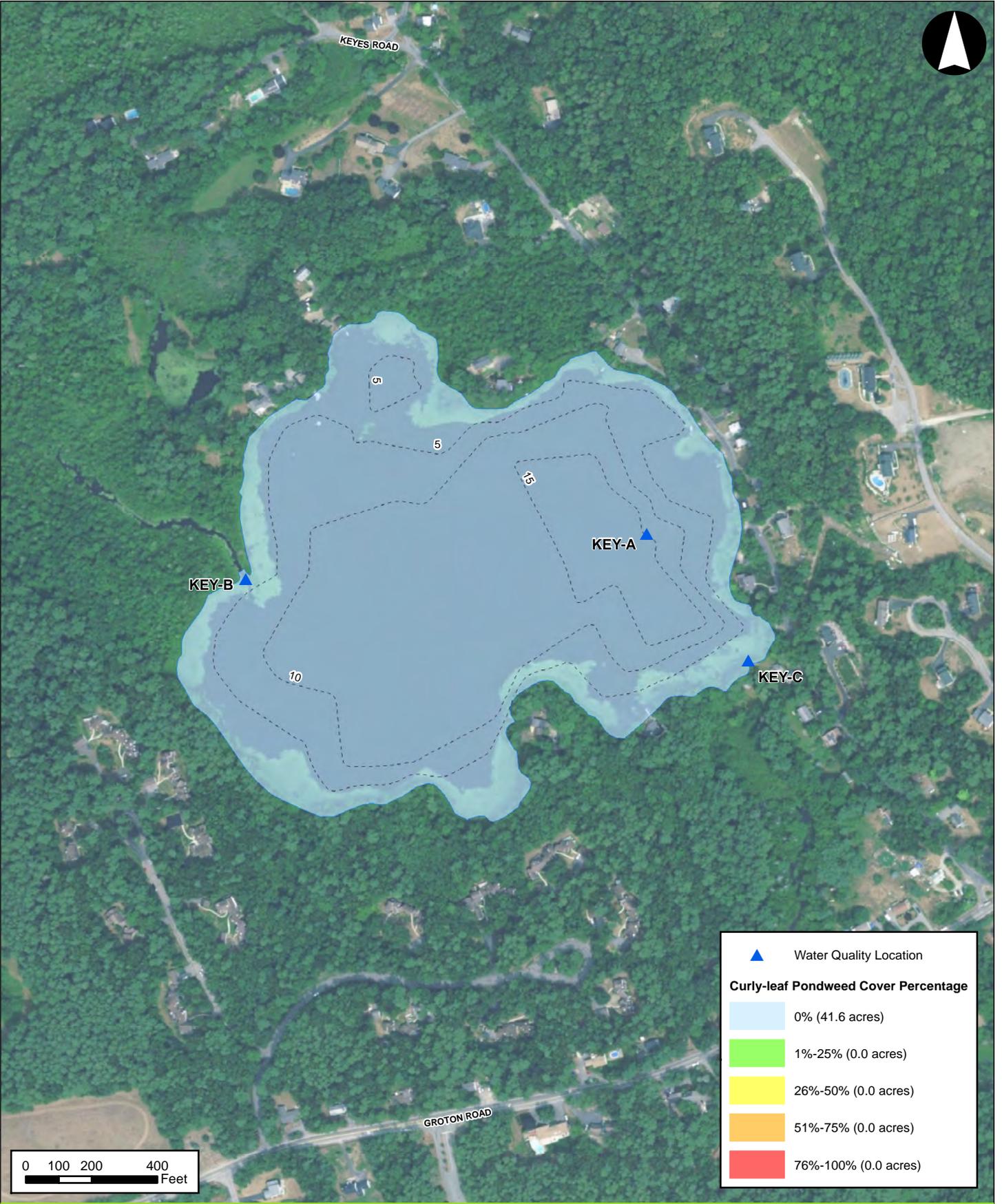
Matt Ladewig, CLM
Senior Scientist

A handwritten signature in black ink that reads "Anna L. Chase".

Anna Chase
Environmental Scientist

Attachments: Figures



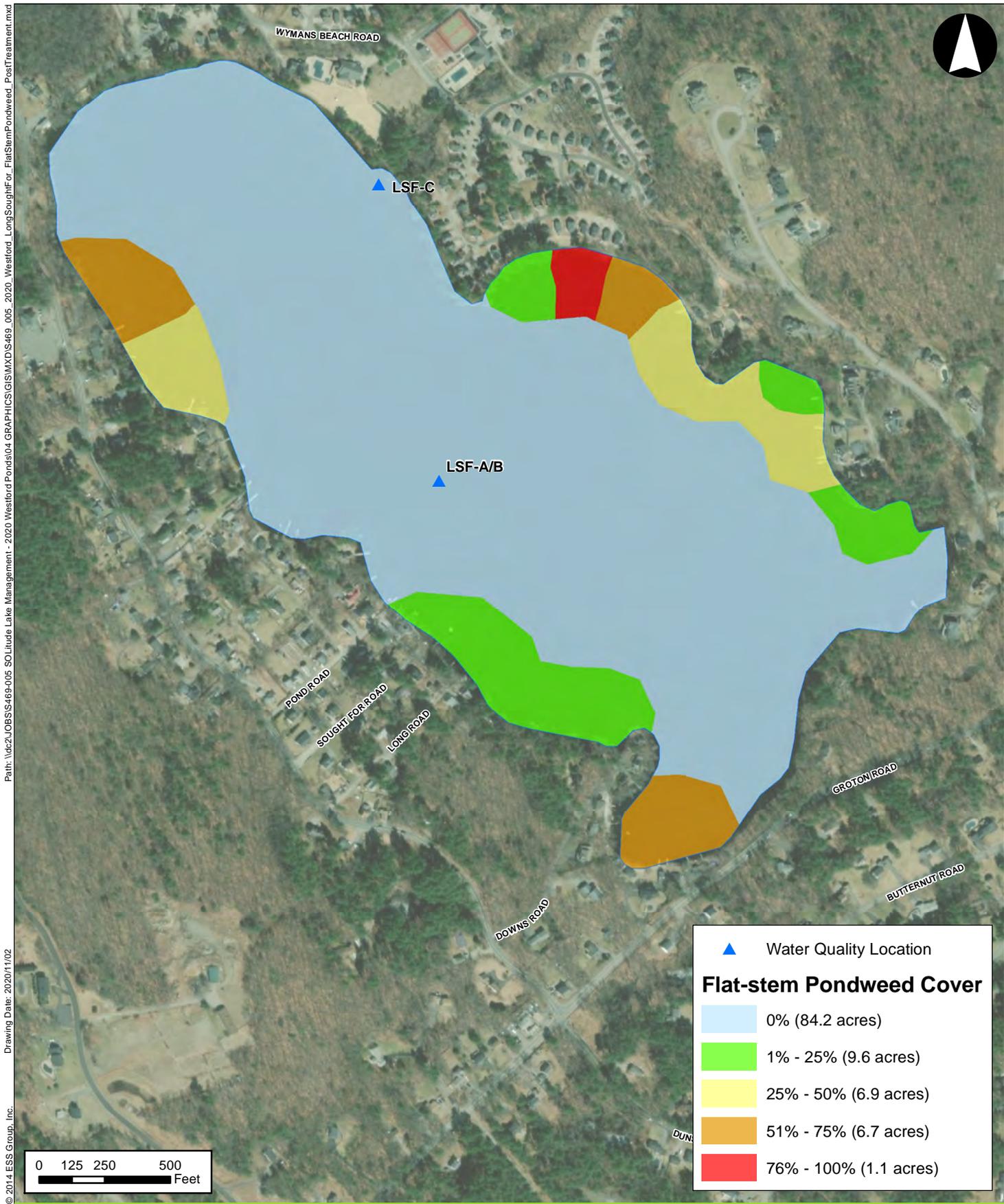


Solitude Lake Management LLC
Westford, Massachusetts
1 inch = 400 feet
Source: 1) USDA, NAIP Imagery, 2016
2) MassGIS, Major Roads, 2003
3) ESS, Bathymetry, 2015 4) ESS, GPS Data, 2020

**Keys Pond
Curly-leaf Pondweed
Post-treatment (October 2020)**

***No invasive species found.**

Figure 1



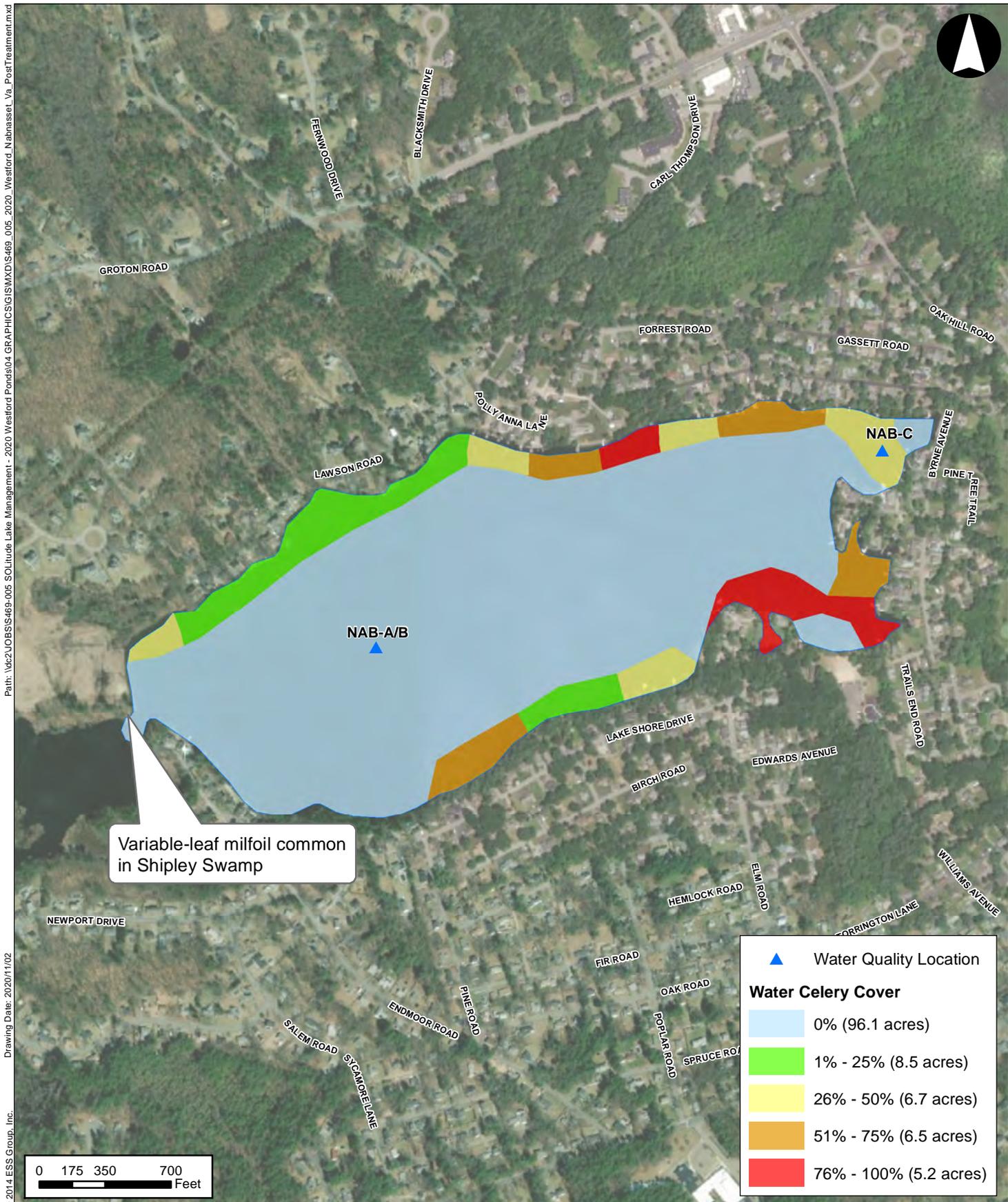
Path: \\dc2\JOBS\S469-005 SOLITUDE Lake Management - 2020 Westford Ponds\04 GRAPHICS\GIS\MXD\S469_005_2020_Westford_LongSoughtFor_FlatStemPondweed_PostTreatment.mxd
 Drawing Date: 2020/11/02
 © 2014 ESS Group, Inc.



Solitude Lake Management LLC
 Westford, Massachusetts
 1 inch = 500 feet
 Source: 1) ESRI, World Imagery, 2020
 2) MassGIS, Major Roads, 2003
 3) ESS, GPS Data, 2020

**Long Sought-For Pond
 Flat-stem Pondweed
 Post-treatment (October 2020)**

Figure 2



Path: \\kcz2\JOBS\S469-005 SOLitude Lake Management - 2020 Westford Ponds\04 GRAPHICS\GIS\WXD\S469_005_2020_Westford_Nabnasset_Va_PostTreatment.mxd
 Drawing Date: 2020/11/02
 © 2014 ESS Group, Inc.



▲ Water Quality Location

Water Celery Cover

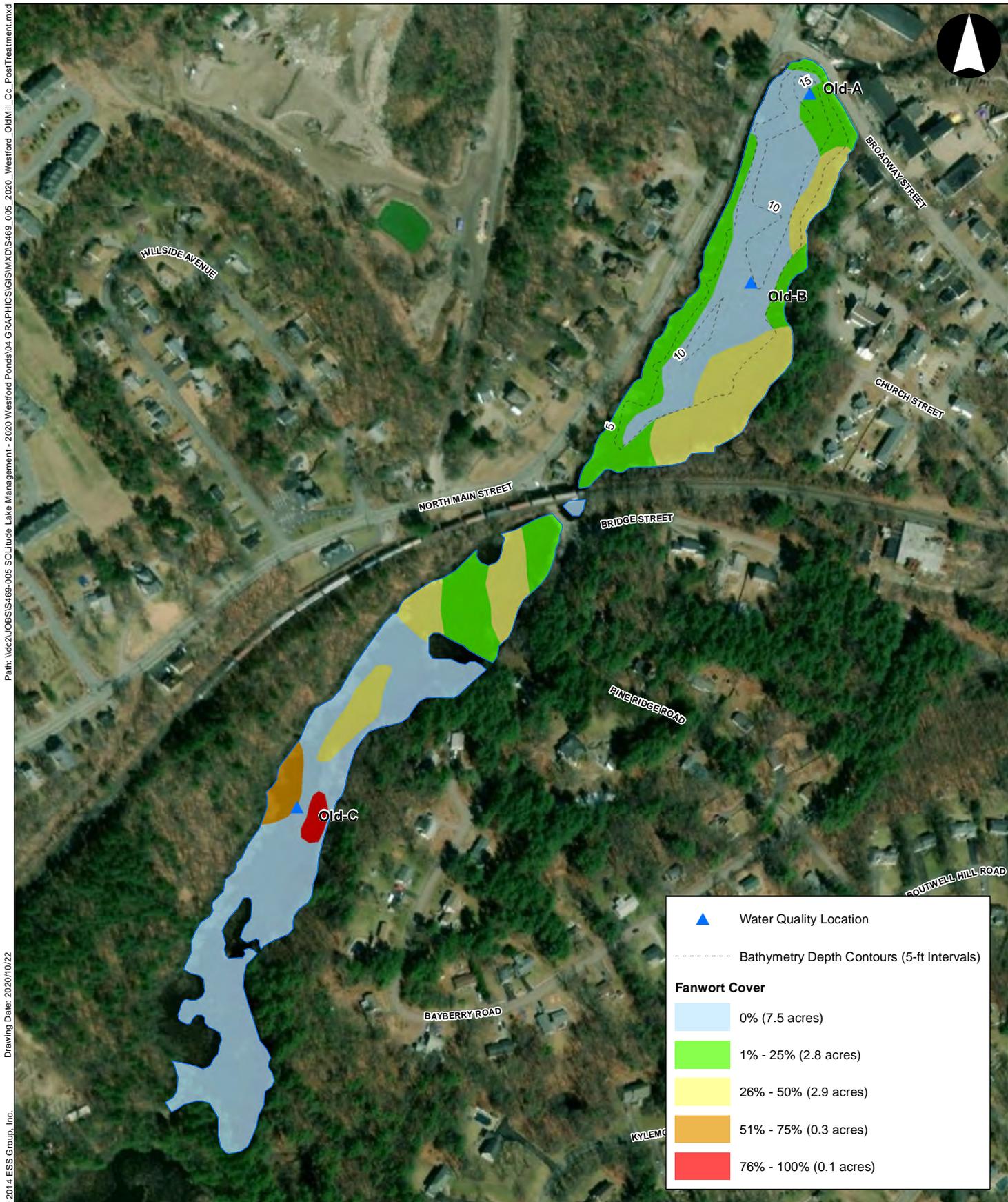
- 0% (96.1 acres)
- 1% - 25% (8.5 acres)
- 26% - 50% (6.7 acres)
- 51% - 75% (6.5 acres)
- 76% - 100% (5.2 acres)



Solitude Lake Management LLC
 Westford, Massachusetts
 1 inch = 700 feet
 Source: 1) ESRI, World Imagery, 2020
 2) MassGIS, Major Roads, 2003
 3) ESS, GPS Data, 2020

Nabnasset Lake
Water Celery and Variable-Leaf Milfoil
Post-treatment (October 2020)

Figure 3



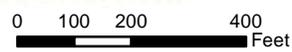
Path: \\ac2jobs\S469-005 SOLitude Lake Management - 2020 Westford Ponds\04 GRAPHICS\GIS\MXD\S469_005_2020_Westford_OldMill_Cc_PostTreatment.mxd
 Drawing Date: 2020/10/22
 © 2014 ESS Group, Inc.

	Water Quality Location
	Bathymetry Depth Contours (5-ft Intervals)
Fanwort Cover	
	0% (7.5 acres)
	1% - 25% (2.8 acres)
	26% - 50% (2.9 acres)
	51% - 75% (0.3 acres)
	76% - 100% (0.1 acres)



Solitude Lake Management LLC
 Westford, Massachusetts

1 inch = 334 feet



Source: 1) ESRI, World Imagery, 2018
 2) MassGIS, Major Roads, 2003
 3) ESS, Bathymetry, 2015
 4) ESS, GPS Data, 2020

Old Mill/Graniteville Pond
Fanwort
Late Season (October 2020)

Figure 4



Path: \\c2\JOBS\S469-005_Solitude_Lake_Management - 2020\Westford Pond\04_Graphics\GIS\MXD\S469_005_2020_Westford_OldMill_Mh_PostTreatment.mxd
 Drawing Date: 2020/10/22
 © 2020 ESS Group, Inc.

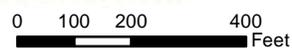
	Water Quality Location
	Bathymetry Depth Contours (5-ft Intervals)
Variable-leaf Milfoil Cover	
	0% (12.7 acres)
	1% - 25% (0.6 acres)
	26% - 50% (0.2 acres)
	51% - 75% (0 acres)
	76% - 100% (acres)



Solitude Lake Management LLC
Westford, Massachusetts

1 inch = 334 feet

Source: 1) ESRI, World Imagery, 2019
 2) MassGIS, Major Roads, 2003
 3) ESS, Bathymetry, 2015
 4) ESS, GPS Data, 2020



Old Mill/Graniteville Pond
Variable-leaf Milfoil
Late Season (October 2020)

Figure 5



Path: J:\S469-004_Solitude Lake Management- 2019 Westford Ponds Monitoring\04_GRAPHICS\GIS\MXD\2019_PostTreatment\S469_004_2019_Westford_Burges_WQ_PostTreatment.mxd
 Drawing Date: 2019/09/19
 © 2014 ESS Group, Inc.

	Water Quality Location
	Pond Outline (27.1 acres)*



Solitude Lake Management LLC
 Westford, Massachusetts

1 inch = 400 feet
 Source: 1) USDA, NAIP Imagery, 2016
 2) MassGIS, Major Roads, 2003
 3) ESS, GPS Data, 2020

Burges Pond
Late Season (October 2020)

***No invasive species found.**

Figure 6

Path: J:\S469-004_Solitude Lake Management-2019\Westford Forests Monitoring\04_Graph\GIS\MXD\2019_PostTreatment\S469_004_2019_Westford_Kennedy_WO_PostTreatment.mxd
Drawing Date: 2019/09/19
© 2014 ESS Group, Inc.



▲ Water Quality Location
□ Pond Outline (17.3 acres)*



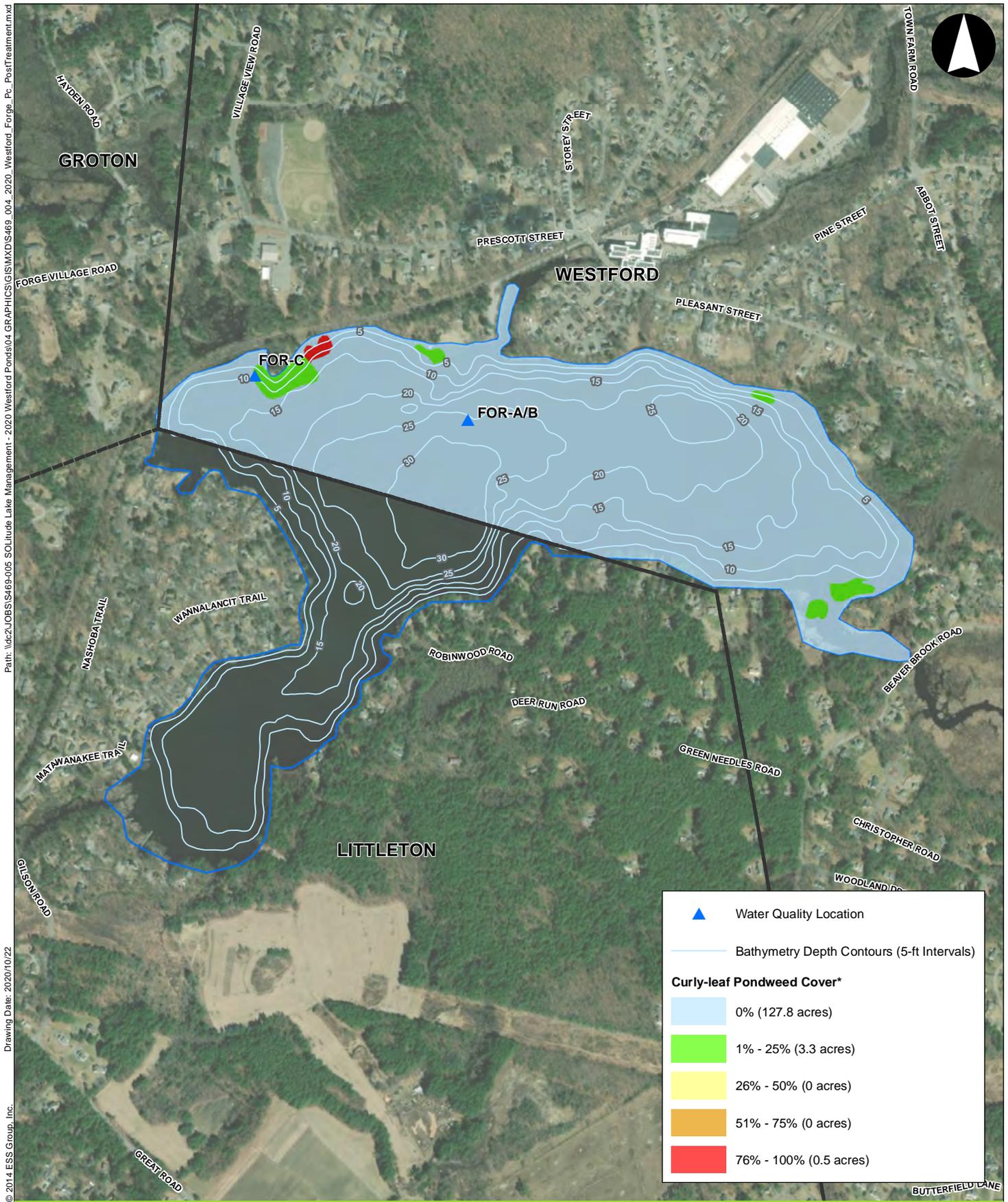
Solitude Lake Management LLC
Westford, Massachusetts

1 inch = 250 feet
Source: 1) USDA, NAIP Imagery, 2016
2) MassGIS, Major Roads, 2003
3) ESS, GPS Data, 2020

Kennedy Pond
Late Season (October 2020)

***No invasive species found.**

Figure 7



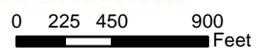
Path: \\dc2\JOBS\S468-005 SOLITUDE Lake Management - 2020 Westford Ponds\04 GRAPHICS\GIS\MXD\S468_004_2020_Westford_Forge_Pc_PostTreatment.mxd
 Drawing Date: 2020/10/22
 © 2014 ESS Group, Inc.



Solitude Lake Management LLC
 Westford, Massachusetts

1 inch = 900 feet

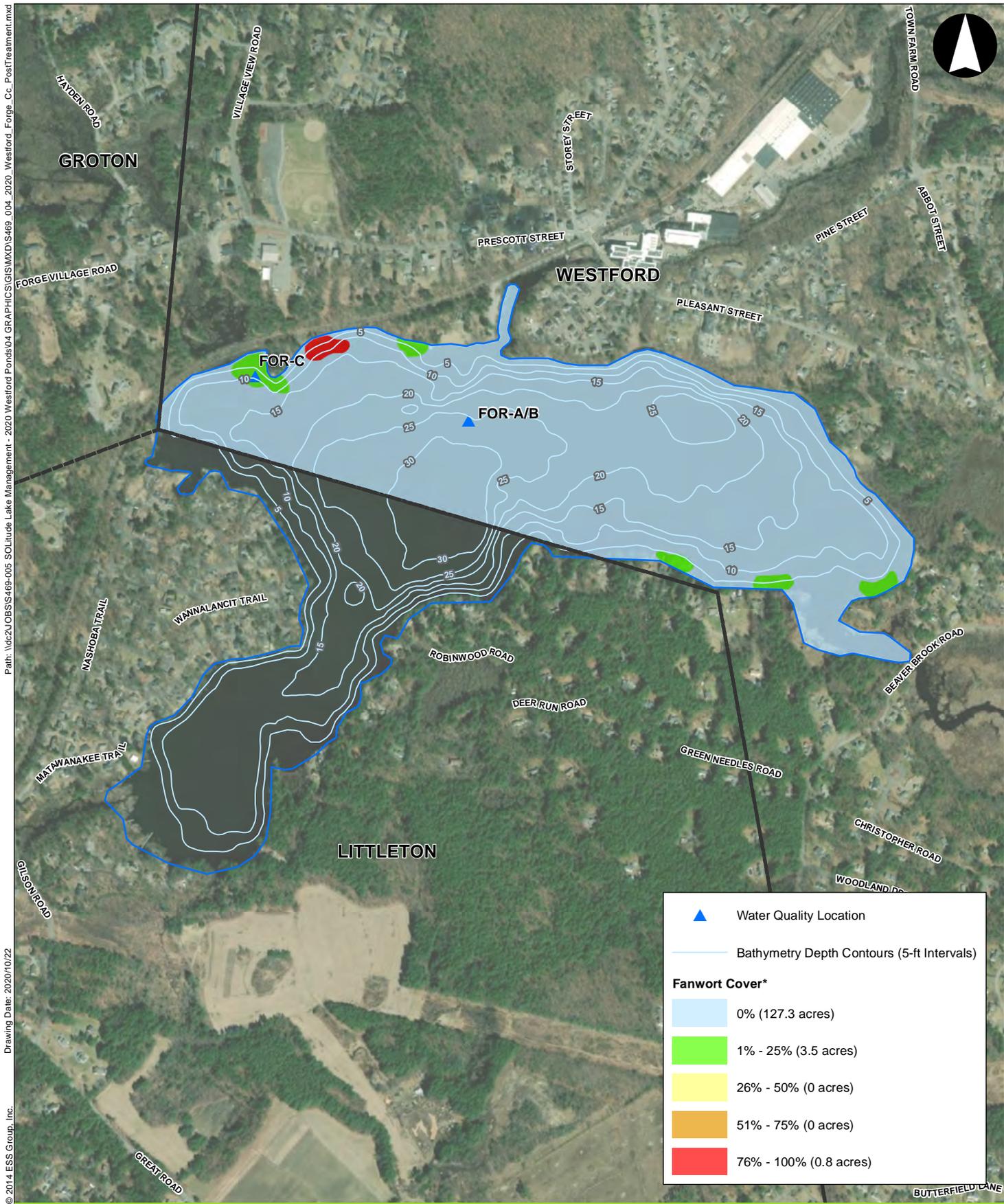
- Source: 1) ESRI, World Imagery, 2019
 2) MassGIS, Major Roads, 2003
 3) ESS, GPS Data, 2020
 4) Contours based on MA DFW "Forge Pond", 2019



*Survey area limited to Westford.

Forge Pond
Curly-leaf Pondweed
Late Season (October 2020)

Figure 8



Path: \\dcs2\JOBS\S468-005 SOLitude Lake Management - 2020\Westford Ponds\04 GRAPHICS\GIS\MXD\S468_004_2020_Westford_Forge_Cc_PostTreatment.mxd
 Drawing Date: 2020/10/22
 © 2014 ESS Group, Inc.

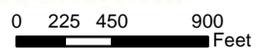
	Water Quality Location
	Bathymetry Depth Contours (5-ft Intervals)
Fanwort Cover*	
	0% (127.3 acres)
	1% - 25% (3.5 acres)
	26% - 50% (0 acres)
	51% - 75% (0 acres)
	76% - 100% (0.8 acres)



Solitude Lake Management LLC
 Westford, Massachusetts

1 inch = 900 feet

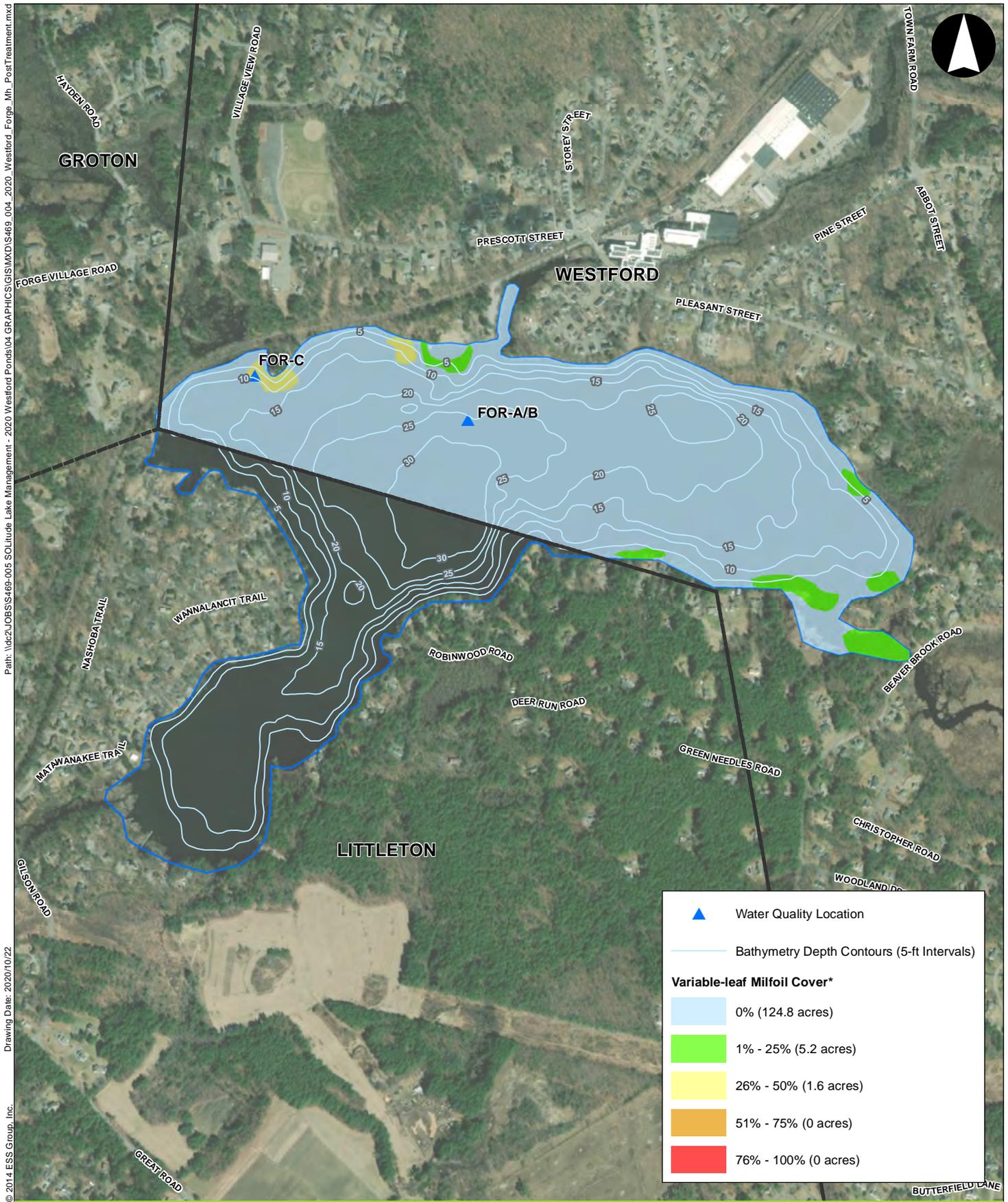
Source: 1) ESRI, World Imagery, 2019
 2) MassGIS, Major Roads, 2003
 3) ESS, GPS Data, 2020
 4) Contours based on MA DFW "Forge Pond", 2019



*Survey area limited to Westford.

Forge Pond
Fanwort
Late Season (October 2020)

Figure 9



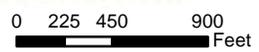
Path: \\dc2\JOBS\469-005 SOLitude Lake Management - 2020 Westford Ponds\04 GRAPHICS\GIS\MXD\S469_004_2020_Westford_Forge_Mh_PostTreatment.mxd
 Drawing Date: 2020/10/22
 © 2014 ESS Group, Inc.



Solitude Lake Management LLC
 Westford, Massachusetts

1 inch = 900 feet

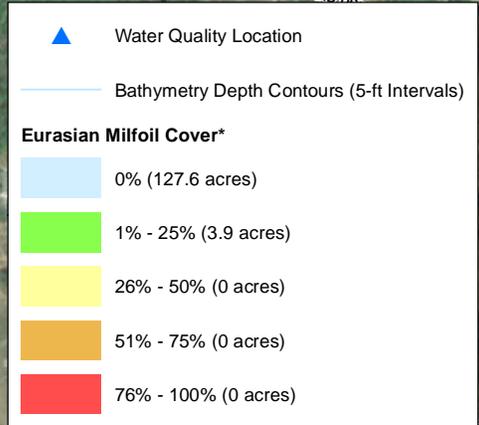
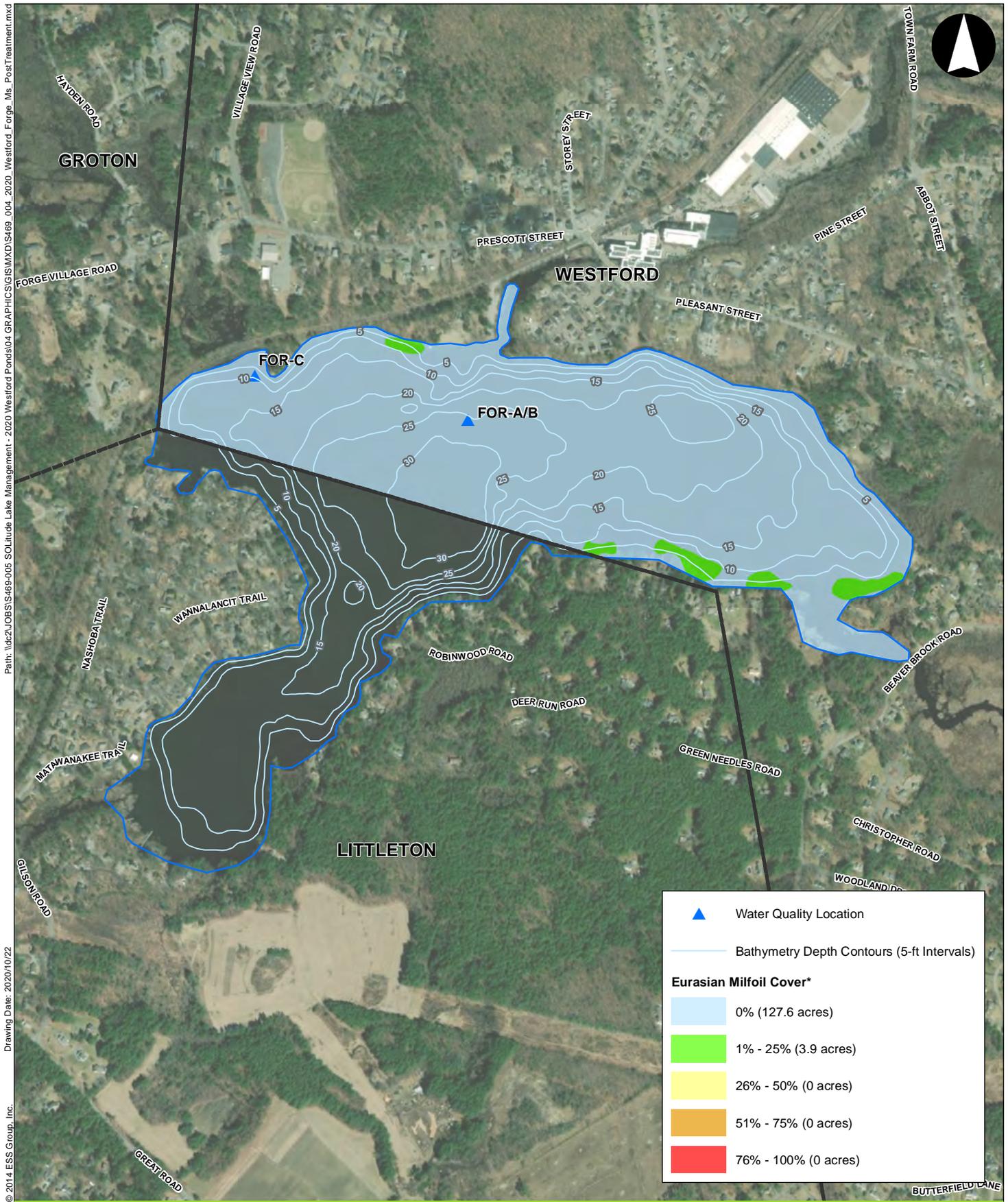
- Source: 1) ESRI, World Imagery, 2019
 2) MassGIS, Major Roads, 2003
 3) ESS, GPS Data, 2020
 4) Contours based on MA DFW "Forge Pond", 2019



*Survey area limited to Westford.

Forge Pond
Variable-leaf Milfoil
Late Season (October 2020)

Figure 10



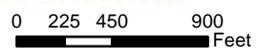
Path: \\dc2\JOBS\S469-005 SOLitude Lake Management - 2020 Westford Ponds\04 GRAPHICS\GIS\MXD\S469_004_2020_Westford_Forge_Ms_PostTreatment.mxd
 Drawing Date: 2020/10/22
 © 2014 ESS Group, Inc.



Solitude Lake Management LLC
 Westford, Massachusetts

1 inch = 900 feet

Source: 1) ESRI, World Imagery, 2019
 2) MassGIS, Major Roads, 2003
 3) ESS, GPS Data, 2020
 4) Contours based on MA DFW "Forge Pond", 2019



*Survey area limited to Westford.

Forge Pond
Eurasian Milfoil
Late Season (October 2020)

Figure 11