Lakes and Ponds Management and Preservation Program Plan

Town of Westford, Massachusetts

Supported by Westford Community Preservation Act funds

Burge's Pond, Westford, May 2014

PREPARED FOR
Town of Westford
55 Main Street
Westford, Massachusetts 01866

PREPARED BY
ESS Group, Inc.
100 Fifth Avenue, 5th Floor
Waltham, Massachusetts 02451

Project No. W314-000
Revised December 11, 2014

www.essgroup.com

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TABLE OF CONTENTS

TABLES

FIGURES

APPENDICES

EXECUTIVE SUMMARY

ESS Group, Inc. (ESS) was contracted by the Town of Westford, Massachusetts (the Town) in early 2014 to prepare a Lakes and Ponds Management and Preservation Program Plan (Lakes Management Plan) for the nine ponds located within the Town that offer some degree of public access and use. The Town's stated goals were to 1) provide for the ongoing assessment of the health of the ponds, 2) identify any threats or issues which may compromise the short-term or long-term health of the ponds, and 3) develop recommendations for management strategies and/or future studies that will ensure the preservation and/or enhancement of the ponds.

Previously Unstudied Ponds

Of the nine ponds included in the Lakes Management Plan, five ponds had not previously been formally studied or managed, including Keyes, Burge's, Grassy, Old Mill/Graniteville, and Kennedy Ponds.

The assessment of these ponds comprised three primary elements: water quality sampling, aquatic plant surveys, and zooplankton and phytoplankton sampling. Water quality sampling was conducted during the spring and summer, while aquatic plant surveys and plankton sampling were conducted during the summer only.

Based on the results of the field-based assessment, the overall condition of each of the five previously unstudied ponds was classified as *Excellent*, *Good*, *Fair*, or *Poor*. Among the five ponds, the overall condition (including water quality and biological conditions) was as follows:

- Keyes, Burge's, and Old Mill/Graniteville Ponds were classified as *Fair*. Each will need additional management attention to ensure that ecological and recreational value do not continue to degrade.
- Grassy and Kennedy Ponds were classified as *Good* and do not appear to face an immediate threat. Therefore, minimal management, primarily in the form of monitoring, is currently necessary to preserve the condition of these ponds.

Ongoing monitoring was recommended for each of the five previously unstudied ponds to track overall conditions, provide early detection of future invasive species or other emerging management issues, and provide for periodic evaluation of trends and updates to the monitoring or management program. Monitoring of all five ponds will require an estimated total of $80,000 over five years. Volunteer education and monitoring through the Massachusetts Weed Watchers program and Westford Stream Team is also encouraged.

Each of the previously unstudied ponds were also prioritized for management action to maintain or improve the condition of the pond. Permitting of the management plan for all of these ponds together is anticipated to cost $17,500, assuming it can be handled as one filing. Estimated costs to actually implement the management plan for each of the five ponds, in order of priority, are as follows:

1. Keyes Pond, which will require an estimated total of $107,000 to implement the recommended plan over the next five years. This includes $34,600 in Year 1 to begin management of the pond. Management actions recommended for Keyes Pond include chemical treatment for nuisance plants and algae, supplemental diver/hand harvesting of nuisance plants, and biological control of purple loosestrife.
2. Burge's Pond, which will require an estimated total of $57,200 to implement the recommended plan over the next five years. This includes $18,800 in Year 1 to begin treatment of the pond. Management actions recommended for Burge's Pond include chemical treatment for nuisance plants, supplemental diver/hand harvesting of nuisance plants, and biological control of purple loosestrife.

3. Old Mill/Graniteville Pond, which will require an estimated total of $72,500 to implement the recommended plan over the next five years. This includes $26,100 in Year 1 to begin treatment of the pond. Management actions recommended for Old Mill/Graniteville Pond include chemical treatment for nuisance plants, supplemental diver/hand harvesting of nuisance plants, and biological control of purple loosestrife. Winter drawdown is a low-cost nuisance plant management tool that should be more thoroughly assessed for feasibility at Old Mill/Graniteville Pond.
4. Kennedy Pond, which will require an estimated total of $12,500 to implement the recommended plan over the next five years. This includes $2,500 in Year 1 to begin management of the pond. Management actions recommended for Kennedy Pond include hand harvesting of nuisance plants.
5. Grassy Pond requires monitoring over the next five years.

An additional action recommended for all ponds is undertaking an initial stormwater assessment study, to identify opportunities to reduce loading of sediments and nutrients from stormwater sources watershed. If stormwater is assessed for all ponds together, the estimated cost would be $15,000.

Previously Studied Ponds

In addition, four ponds had previously been formerly studied and/or managed, including Long Sought for Pond, Nabnasset Lake, Forge Pond and Heart Pond. The Town provided ESS with existing reports on the four previously studied ponds, which were reviewed and synthesized to extract information relevant to the Lakes Management Plan.

The information reviewed indicated that each of the previously studied ponds have faced some significant management challenges, including aquatic invasive species and, in some cases, algae blooms or other water quality issues. However, pond-specific water quality and aquatic plant monitoring programs are already in place and tailored to the management needs of each pond. Therefore, the primary recommendation for these ponds is that the management and monitoring programs continue to be implemented and periodically updated or expanded to address the management challenges and maintain or improve water quality. The ponds that have experienced recurring algae blooms or hypolimnetic dissolved oxygen depletion, including Long Sought-for Pond, Nabnasset Lake and Heart Pond would benefit from an updated nutrient budget study to quantify the sources and target the most cost-effective source reduction actions at each pond. Such a study could be completed for $5,000 to $10,000, depending on scope of the potential nutrient sources.

INTRODUCTION

ESS Group, Inc. (ESS) was contracted by the Town of Westford (the Town) to prepare a Lakes and Ponds Management and Preservation Program Plan (Lakes Management Plan) for the nine ponds located within the Town that provide some degree of public access and use. The goals of the Lakes Management Plan as stated by the Town are to:

1. Provide for the ongoing assessment of the health of the ponds, including their ability to provide important natural resources values;
2. Identify any threats or issues which may compromise the short-term or long-term health of the ponds and their ability to provide these values; and
3. Develop recommendations for management strategies and/or future studies that will ensure the preservation and/or enhancement of the ponds.

The nine ponds included in the Plan were divided into two groups: those for which field investigations and/or organized management actions had been completed in the past (previously studied ponds), and those for which no formal studies or management had previously been conducted (previously unstudied ponds).

- The five previously-unstudied ponds were Keyes Pond (42.2 acres), Burge's Pond (27.1 acres), Grassy Pond (6.7 acres), Old Mill/Graniteville Pond (14.8 acres), and Kennedy Pond (17.4 acres) (Figure 1).
- The four previously studied ponds were Long Sought for Pond (100.7 acres), Nabnasset Lake (116.3 acres), Forge Pond (190.8 acres, also partially located in the Town of Littleton), and Heart Pond (83.6 acres, also partially located in the Town of Chelmsford) (Figure 1).

Acknowledgments

Funding for this Plan was provided through the Westford Community Preservation Act.

APPROACH

ESS's approach to developing the Westford Lakes Management Plan included conducting field studies to collect additional information on the previously unstudied ponds and reviewing other publically-available information, including GIS data layers and readily available information provided by the Town for the previously studied ponds. The methods are presented in more details in the following sections.

Assessment of Previously Unstudied Ponds

ESS's assessment of the five previously unstudied ponds included field studies and review of publically available information, including GIS data. Field studies of the previously unstudied ponds were comprised of three primary elements:

1. water quality
2. aquatic plant community
3. zooplankton and phytoplankton community

The methods used for the field assessments of the previously unstudied ponds are described in the following sections.

Water Quality Sampling

ESS conducted water quality sampling at the five previous-unstudied ponds during two discrete time periods. The first round of water quality sampling was conducted during early May 2014 (spring sampling event), and the second round of sampling was conducted during early August 2014 (summer sampling event). Water quality sampling locations were established within each pond at the deep hole, at one other location in the pond, and at the mouth of any flowing perennial tributary of the pond (Figure 2).

At each water quality sampling location, ESS measured the following water quality parameters: dissolved oxygen, temperature, pH, conductivity, turbidity, total depth, and Secchi depth. Additionally, ESS conducted a water quality profile at the deep hole location of each pond, which measured dissolved oxygen, temperature, and conductivity at regular vertical intervals through the water column.

ESS also collected a surface water sample at each water quality sampling location for analysis by a state-certified laboratory for the following analytes: ammonia nitrogen, nitrate, and total phosphorus. In addition, at the deep hole location of each pond, ESS collected a surface water sample for chlorophyll *a* analysis and a water sample from the bottom of the pond for total phosphorus analysis.

Aquatic Plant Survey

ESS conducted aquatic vegetation surveys at each of the five previously unstudied ponds during early August 2014. Aquatic vegetation survey locations were established within each pond to provide adequate coverage for accurately mapping the aquatic plant community in each pond. A plant rake was used to collect plants for field identification at each location, and a sub-meter accurate GPS receiver was used to collect location and plant community data at each survey location. At each survey location, ESS identified all species of submergent, floating, and emergent aquatic plants, determined the extent of any invasive plant infestations, and assigned the location an overall cover and biovolume classification (Figure 3). Plant cover is defined as the proportion of the surface area of the location which is taken up by plants, while plant biovolume is defined as the proportion of the water column with plant growth.

Zooplankton and Phytoplankton Assessment

ESS collected one phytoplankton and one zooplankton sample from the deep hole location of each of the previously unstudied ponds during early August. Phytoplankton samples were collected as a grab sample from the mixed surface layer of each pond. Zooplankton samples were collected using a fine (64-μm) mesh plankton net which was lowered vertically through the water column of each pond. Due to shallow water depths at Grassy Pond, the plankton net was towed horizontally through the surface of the pond.

Phytoplankton and zooplankton samples were preserved in the field and returned to ESS's office for identification and qualitative analysis under the microscope by a qualified taxonomist.

Assessment of Previously Studied Ponds

The Town provided ESS with existing reports on the four previously studied ponds in Westford. ESS scientists examined and synthesized these reports to extract the information relevant to the Lakes Management Plan, including identification of monitoring methods and management actions.

RESULTS: PREVIOUSLY UNSTUDIED PONDS

Keyes Pond

Water Quality

Keyes Pond is a 42-acre pond that is approximately 7 m deep at its deepest point, which is located in the middle of the eastern portion of the pond. Dissolved oxygen concentrations at Keyes Pond were above the state standard during the spring sampling event and were relatively high during the summer sampling event (Table A). However, the pond became anoxic (dissolved oxygen concentrations ≤ 1.0 mg/L) near the bottom in summer (Figure A). Specific conductance values were somewhat elevated, indicating concentrations of dissolved ionic solids (salts), in the water. Turbidity values were low and pH values were within acceptable parameters, though pH was elevated (highly alkaline) at one location (KEY-D) during the summer sampling event. Secchi values were somewhat poor at the deep hole (KEY-A), were somewhat better at location KEY-B, and were visible on the bottom at both the tributary location (KEY-C) and outlet station (KEY-D) during both sampling events.

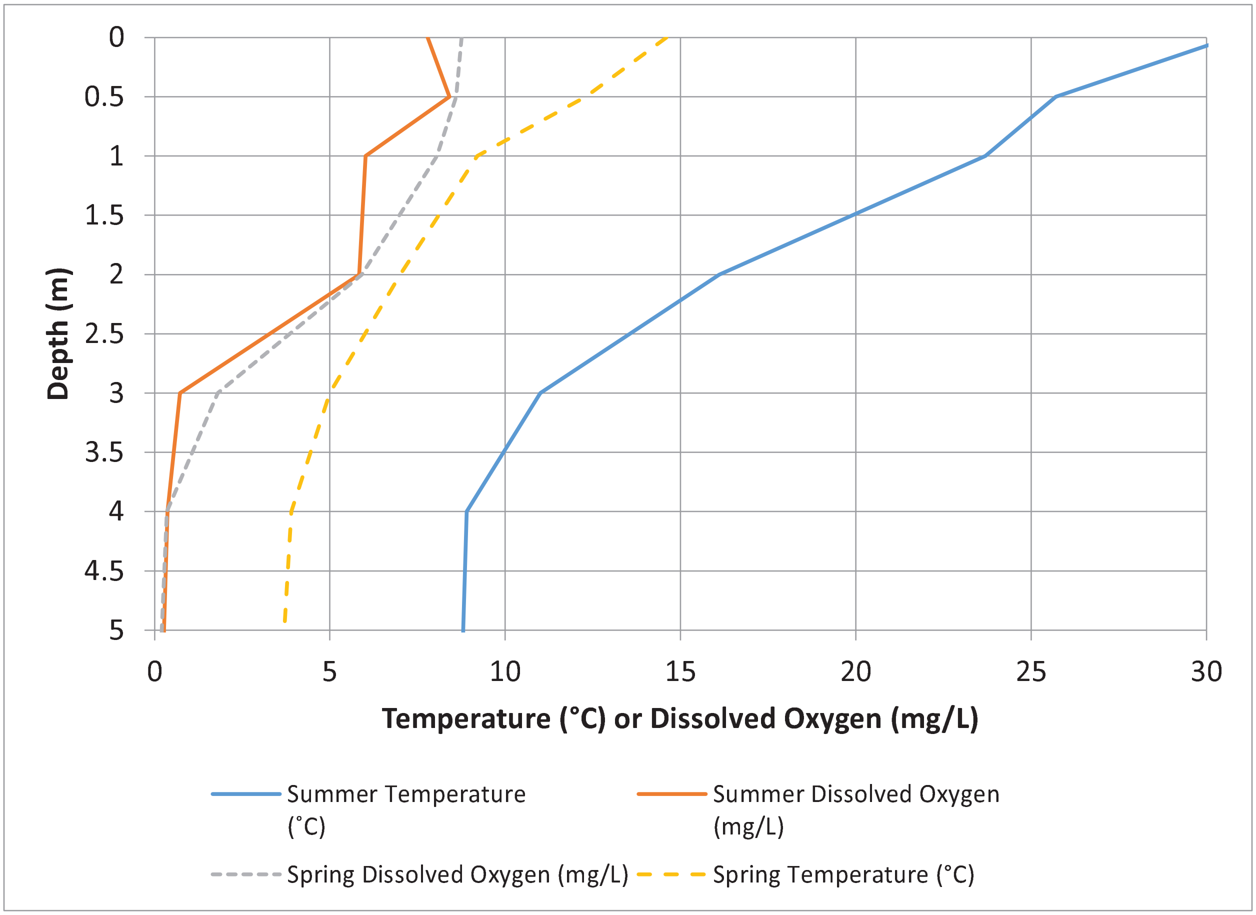

Figure A. Temperature and Dissolved Oxygen Profile at Keyes Pond

Phosphorus and dissolved inorganic nitrogen (ammonia and nitrate) in surface waters of Keyes Pond did not appear to be excessive (Table A). Generally, phosphorus concentrations below 0.02 mg/L are considered desirable. However, phosphorus was particularly high in the hypolimnion, where it exceeded 0.5 mg/L. Under some conditions, hypolimentic phosphorus may “leak” into the epilimnion, either through physical or chemical processes, where it fuels the growth of algae. The summer dissolved oxygen profile (Figure A) shows some potential evidence of this at 2.0 meters deep.

Table A. Water Quality Results at Keyes Pond

Site ID		KEY-A	KEY-B	KEY-C	KEY-D
Date	Spring	5/9/2014	5/9/2014	5/9/2014	5/9/2014
	Summer	8/5/2014	8/5/2014	8/5/2014	8/5/2014
Time	Spring	11:05	11:18	10:53	10:35
	Summer	13:38	13:17	13:07	12:42
Temperature (°C)	Spring	15.5	15.7	14.7	15.9

Site ID		KEY-A	KEY-B	KEY-C	KEY-D
	Summer	30.7	30.1	30.8	29.4
Dissolved Oxygen (mg/L)	Spring	8.76	8.58	4.75	8.48
	Summer	7.79	7.92	7.57	6.75
Dissolved Oxygen (%)	Spring	89.3	86.7	49.2	86.1
	Summer	104.2	103.3	92.0	92.4
Specific Conductance (µS/cm)	Spring	200	200	202	200.7
	Summer	220.3	218.8	222	240
pH (SU)	Spring	6.75	6.76	6.4	6.96
	Summer	8.00	7.99	8.13	9.35
Turbidity (NTU)	Spring	0.39	0	0.61	0.96
	Summer	1.63	1.37	0.88	2.06
Secchi Depth (m)	Spring	2.7	3	Bottom	Bottom
	Summer	1.8	1.75	Bottom	Bottom
Total Depth (m)	Spring	6.1	4.6	1.2	0.6
	Summer	5.8	3.0	1.0	0.3
Ammonia (mg/L)	Spring	0.089	0.10	0.11	0.078
	Summer	0.088	0.050	0.070	0.12
Nitrate (mg/L)	Spring	ND	ND	ND	ND
	Summer	ND	ND	ND	ND
Total Phosphorus (mg/L) (Surface)	Spring	0.012	0.02	0.017	0.014
	Summer	0.015	ND	0.012	0.021
Total Phosphorus (mg/L) (Bottom)	Spring	NS	NS	NS	NS
	Summer	0.51	NS	NS	NS
Chlorophyll-*a* (mg/m3)	Spring	4.13	NS	NS	NS
	Summer	5.9	NS	NS	NS

ND = Non-detect. Analyte concentration did not exceed laboratory detection limit.

Aquatic Plants

Thirteen species of aquatic plants were observed in Keyes Pond (Table B). Variable-leaf milfoil (*Myriophyllum heterophyllum*) was the only invasive aquatic plant species detected in Keyes Pond. The variable-leaf milfoil infestation in Keyes Pond was found to be very dense along nearly the entire shoreline of the pond, covering a total of 11.6 acres. In many areas, the native coontail (*Ceratophyllum demersum*) was also found in dense patches and was often co-located with variable-leaf milfoil.

Two emergent invasive species, common reed (*Phragmites australis*) and purple loosestrife (*Lythrum salicaria*), were also found growing along the shoreline of the pond in some areas.

Table B. Aquatic Plants Observed at Keyes Pond

Common Name	Scientific Name	Native or Exotic
Watershield	*Brasenia schreberi*	Native
Coontail	*Ceratophyllum demersum*	Native
Spikerush	*Eleocharis sp.*	Native

Common Name	Scientific Name	Native or Exotic
Western Waterweed	*Elodea nuttallii*	Native
Variable-leaf Milfoil	*Myriophyllum heterophyllum*	Exotic
Yellow Water Lily	*Nuphar lutea variegata*	Native
White Water Lily	*Nymphaea odorata*	Native
Floating-leaf Pondweed	*Potamogeton epihydrus*	Native
Robbins' Pondweed	*Potamogeton robbinsii*	Native
Humped Bladderwort	*Utricularia gibba*	Native
Flat-leaf Bladderwort	*Utricularia intermedia*	Native
Common Bladderwort	*Utricularia macrorhiza*	Native
Purple Bladderwort	*Utricularia purpurea*	Native

Aquatic plant cover was very high throughout virtually the entire shoreline of Keyes Pond, however, due to the relatively steep drop-off in bathymetry, very few plants were found away from the immediate shoreline of the pond. Plant biovolume was also high along the shoreline of the pond, particularly in protected coves, such as those in the southeastern portion of the pond. Areas exposed to more wave action were characterized by sandy sediments with lower plant biovolumes.

The shoreline of Keyes Pond is a mix of homes and woods.

Phytoplankton and Zooplankton

Phytoplankton

Phytoplankton were found at high cell densities in Keyes Pond, characteristic of a minor bloom, with the cyanobacterium *Oscillatoria* the most common (Table C). Other cyanobacteria, including *Dolichospermum, Microcystis and Aphanizomenon*, were also present but at lower abundances. Each of these cyanobacteria taxa are known to be potential producers of toxins under the right conditions. Other common but non-harmful phytoplankton taxa observed in the sample include the dinoflagellate *Ceratium* and the synurophyte *Mallomonas*.

Phytoplankton were much more abundant at depth than at the surface, which coincides with field observations of low clarity in the absence of surface scums.

Table C. Summary of Phytoplankton Results at Keyes Pond

Type	Taxon	Abundance
Cyanobacteria	*Aphanizomenon*	rare
	Dolichospermum	common
	Microcystis	common
	Oscillatoria	abundant
Diatom	*Tabellaria*	rare
Dinoflagellate	*Ceratium*	abundant
Golden-brown	*Dinobryon*	rare
Green	*Chlorobotrys*	rare

Type	Taxon	Abundance
	Staurastrum	rare
Synurophytes	*Mallomonas*	common

Zooplankton

The zooplankton community was characterized by only a very low abundance of small- to medium-bodied individuals (Table D). The small rotifer *Kellicottia longispina* was the most commonly encountered taxon. Copepod nauplii (larvae) were also present at moderate abundances. Other taxa, including various copepods and small- to medium-bodied cladocerans, were also present but rare.

Rotifers are ubiquitous zooplankters in aquatic habitats and can survive in water bodies that support few larger-bodied taxa. Their ciliated feeding mechanism allows them to consume a wide variety of phytoplankton (Bogdan and Gilbert 1982).

Table D. Summary of Zooplankton Results at Keyes Pond

Taxon	Relative Abundance	Size
Bosmina longirostrum	Rare	Small
Calanoid copepods	Rare	Small
Cyclopoid copepods	Rare	Small
Copepod nauplii	Common	Small
Kellicottia longispina	Common	Small
Holopedium gibberum	Rare	Medium

Burge's Pond

Water Quality

Burge's Pond is set in a small, wooded valley

Burge's Pond is a 27-acre pond that is approximately 6 m deep at its deepest point, located at the southern end of the pond. Surface water quality at Burge's Pond was fair during both the spring and summer sampling events. During both sampling events, dissolved oxygen levels at the surface were adequate; however, the pond became anoxic near the bottom (Table E, Figure B). Specific conductance and turbidity values were low, and pH values were within acceptable parameters. Secchi disk readings were mixed, but in general water clarity was higher during the summer sampling event compared to the spring event. This may be related to the very high chlorophyll *a* levels measured during the spring sampling event, which suggest that a vernal algae bloom (a normal occurrence following spring turnover of deep lakes) was underway at the time.

Dissolved inorganic nitrogen (ammonia and nitrate) in surface waters of Keyes Pond did not appear to be excessive (Table E). However, phosphorus levels were somewhat elevated (0.02 mg/L or greater) during both spring and summer at the surface and bottom of the pond. In particular, the summer surface phosphorus concentration was quite high (0.068 mg/L) at BUR-A.

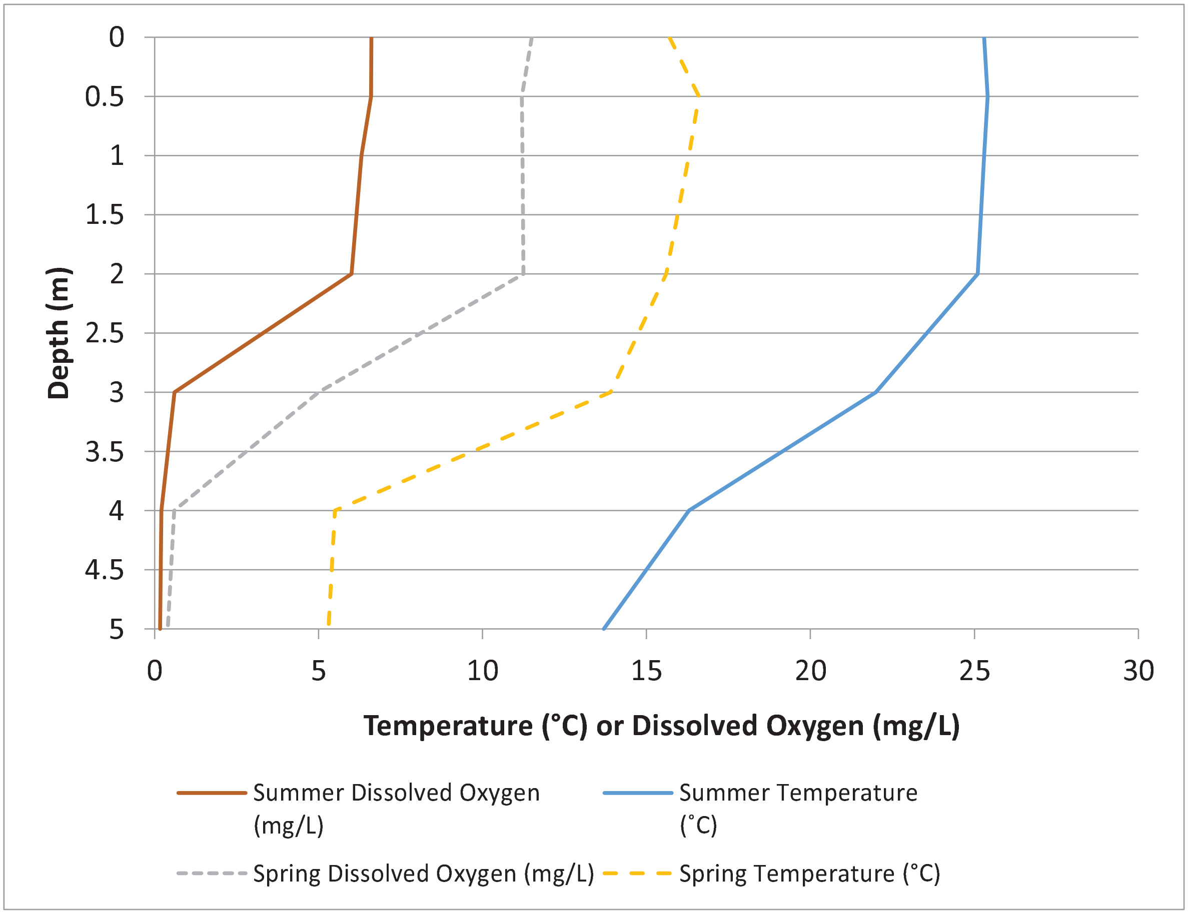

Figure B. Temperature and Dissolved Oxygen Profile at Burges' Pond

Table E. Water Quality Results at Burge's Pond

Site ID		BUR-A	BUR-B
Date	**Spring**	5/8/2014	5/8/2014
	Summer	8/7/2014	8/7/2014
Time	**Spring**	09:16	08:45
	Summer	08:50	09:16
Temperature (°C)	**Spring**	15.7	14.4
	Summer	25.3	24.7
Dissolved Oxygen (mg/L)	**Spring**	11.5	11.49
	Summer	6.61	6.11
Dissolved Oxygen (%)	**Spring**	110.5	112.6
	Summer	80.8	73.5
Specific Conductance (µS/cm)	**Spring**	11.0	12.1

Site ID		BUR-A	BUR-B
	Summer	11.4	12.6
pH (SU)	Spring	6.4	6.5
	Summer	6.3	5.95
Turbidity (NTU)	Spring	4.37	3.39
	Summer	0.72	0.94
Secchi Depth (m)	Spring	2.3	3
	Summer	3.5	3.25
Total Depth (m)	Spring	6.0	4.6
	Summer	7.0	4.5
Ammonia (mg/L)	Spring	0.12	0.11
	Summer	0.12	0.090
Nitrate (mg/L)	Spring	ND	ND
	Summer	ND	ND
Total Phosphorus (mg/L) (Surface)	Spring	0.020	0.025
	Summer	0.068	0.015
Total Phosphorus (mg/L) (Bottom)	Spring	-	-
	Summer	0.025	-
Chlorophyll-*a* (mg/m3)	Spring	77.5	-
	Summer	6.4	-

ND = Non-detect. Analyte concentration did not exceed laboratory detection limit.

Aquatic Plants

Eight aquatic plant species were observed at Burge's Pond (Table F). Of these, variable-leaf milfoil was the only invasive species detected. This species was found in dense stands in many areas along the shoreline of the pond, but was especially prevalent in the northwestern and northeastern portions of the pond. Variable-leaf milfoil beds currently cover 12.0 acres.

Plant cover was high along the entire shoreline of Burge's Pond, but plants were generally absent from the central portions of the pond, except for shallow areas in the middle of the northeastern cove and in the central "neck" of the pond. Plant biovolume was low to moderate over most of the pond, except where variable-leaf milfoil stands occurred along the shoreline, where it was higher.

Table F. Aquatic Plants Observed at Burge's Pond

Common Name	Scientific Name	Native or Exotic
Watershield	*Brasenia schreberi*	Native
Waterwort	*Elatine sp.*	Native
Spikerush	*Eleocharis sp.*	Native
Golden Hedge-hyssop	*Gratiola aurea*	Native
Variable-leaf Milfoil	*Myriophyllum heterophyllum*	Exotic
Yellow Water Lily	*Nuphar lutea variegata*	Native
White Water Lily	*Nymphaea odorata*	Native
Common Bladderwort	*Utricularia macrorhiza*	Native

Phytoplankton and Zooplankton

Phytoplankton

The phytoplankton community was characterized by low overall abundance, with the dinoflagellate *Glenodinium* most common. (Table G). *Cosmarium* and *Scenedesmus*, both green algae, were also present but rare. The only other algae noted in the sample collected at Burge's Pond were benthic (sediment-dwelling) diatoms associated with clumps of suspended sediments.

Table G. Summary of Phytoplankton Results at Burge's Pond

Type	Taxon	Abundance
Diatom	Various benthic species	common
Dinoflagellate	*Glenodinium*	common
Green	*Cosmarium*	rare
	Scenedesmus	rare

Zooplankton

The zooplankton community was characterized by low abundances of small- and medium-bodied individuals (Table H). The most abundant zooplankters were calanoid copepods. *Diaphanosoma* and *Holopedium gibberum* were common cladoceran species. Medium-bodied cyclopoid copepods (including larval nauplii) were also present.

Copepods are typically omnivorous, although feeding preferences change over the lifespan of the organism. Generally, these organisms forage on phytoplankton during their early life stages and become predatory in later developmental stages. Calanoid copepods, in particular, appear to be highly selective when feeding on phytoplankton, with a preference for ciliates (Kerfoot and Kirk 1991, Thorp and Covich 2010).

Among the cladocerans, *Holopedium gibberum* is a highly efficient grazer at low phytoplankton densities (such as those observed in Burge's Pond) and may dominate the zooplankton community under these conditions (Balcer et al. 1984). *Diaphanosoma* is known to be a selective herbivore, preferring smaller green algae and diatoms.

Table H. Summary of Zooplankton Results at Burge's Pond

Taxon	Relative Abundance	Size
Diaphanosoma	Common	Small
Calanoid copepods	Abundant	Medium
Cyclopoid copepods	Rare	Medium
Copepod nauplii	Common	Small
Holopedium gibberum	Rare	Medium

Grassy Pond

Water Quality

Grassy Pond is a very shallow 7-acre softwater pond, approximately 0.9 m deep at its deepest point, which is located in the southeastern part of the water body. Dissolved oxygen concentrations were relatively high during the spring sampling event but were relatively low during the summer sampling event (Table I). Specific conductance values were relatively low during both sampling events, and turbidity values were low during the spring sampling event. However, turbidity values were high during the summer event, and pH values during both events were relatively low (acidic). The Secchi disk was visible on the bottom at all locations during both sampling events.

Dissolved inorganic nitrogen (ammonia and nitrate) in surface waters of Grassy Pond did not appear to be excessive (Table I). However, phosphorus levels were somewhat elevated (0.02 mg/L or greater) particularly during summer, when the surface phosphorus concentration reached 0.2 mg/L at GRA-B. Given the shallow water depth and abundant growth of emergent plants at Grassy Pond, the water body functions much like an emergent wetland and may have naturally higher phosphorus concentrations than deeper water bodies nearby.

Grassy Pond showing clumps of filamentous green algae in May.

Table I. Water Quality Results at Grassy Pond

Site ID		GRA-A	GRA-B
Date	**Spring**	5/8/2014	5/8/2014
	Summer	8/6/2014	8/6/2014
Time	**Spring**	10:30	10:20
	Summer	08:50	08:40
Temperature (°C)	**Spring**	16.6	17.3
	Summer	24.9	23.9
Dissolved Oxygen (mg/L)	**Spring**	9.66	9.25
	Summer	3.50	4.40
Dissolved Oxygen (%)	**Spring**	98.2	95.6
	Summer	41.6	51.8
Specific Conductance (µS/cm)	**Spring**	10.9	11.6
	Summer	18.0	21.0
pH (SU)	**Spring**	5.7	5.8
	Summer	5.61	5.8
Turbidity (NTU)	**Spring**	1.66	0.66
	Summer	14.8	31.5
Secchi Depth (m)	**Spring**	Bottom	Bottom
	Summer	Bottom	Bottom
Total Depth (m)	**Spring**	0.9	0.6
	Summer	0.5	0.1
Ammonia (mg/L)	**Spring**	0.16	0.16
	Summer	0.20	0.35
Nitrate (mg/L)	**Spring**	ND	ND

Site ID		GRA-A	GRA-B
	Summer	ND	ND
Total Phosphorus (mg/L) (Surface)	**Spring**	0.027	0.024
	Summer	0.083	0.20
Total Phosphorus (mg/L) (Bottom)	**Spring**	-	-
	Summer	0.080	-
Chlorophyll-*a* (mg/m3)	**Spring**	15.5	-
	Summer	16.0	-

ND = Non-detect. Analyte concentration did not exceed laboratory detection limit.

Aquatic Plants

Six species of native aquatic plants were documented at Grassy Pond, which was found to be free of invasive, non-native aquatic plant species (Table J). The lack of surface connections with other waterbodies and the absence of easy public access for boating in the pond (due to very shallow water depths) are likely the key reasons why Grassy Pond has been maintained free of aquatic invasive plants.

Filamentous algal growths were prevalent over a large portion of the pond during the initial field visit in May but had declined by the second field visit in August. Although sampling and mapping of the algae was beyond the scope of this study, field observations indicate that the extensive growths were likely to consist of filamentous green algae taxa, such as *Spirogyra*, *Mougeotia,* and *Zygnema*. These species commonly form "clouds" beneath the water surface in spring, then rise to the surface in early to mid-summer as greenish mats. Although they are sometimes considered a nuisance, these algae do not produce toxins.

Plant cover and biovolume were both low to moderate throughout most of the pond, except in the northern cove and in the southwestern corner of the pond, where plant cover and biovolume were dense.

Table J. Aquatic Plants Observed at Grassy Pond

Common Name	Scientific Name	Native or Exotic
Watershield	*Brasenia schreberi*	Native
Water Starwort	*Callitriche heterophylla*	Native
White Water Lily	*Nymphaea odorata*	Native
White Floating Heart	*Nymphoides cordata*	Native
Longleaf Pondweed	*Potamogeton nodosus*	Native
Common Bladderwort	*Utricularia macrorhiza*	Native

Phytoplankton and Zooplankton

Phytoplankton

Phytoplankton in Grassy Pond were abundant overall with a richness of different algal groups (Table K). The community was dominated by the dinoflagellate *Glenodinium*, although *Ceratium* was also common. Globular colonies of *Synura* and solitary *Euglena*, the latter typical of shallow, calm waters, were other common taxa.

Table K. Summary of Phytoplankton Results at Grassy Pond

Type	Taxon	Abundance
Cryptophytes	*Cryptomonas*	rare
Diatom	Various benthic species	rare
Dinoflagellate	*Ceratium*	common
	Gleodinium	abundant
Euglenophytes	*Euglena*	common
	Phacus	rare
Golden-brown	*Dinobryon*	rare
Green	*Chlorobotrys*	rare
Synurophytes	*Synura*	common

Zooplankton

The zooplankton community was characterized by high abundances of individuals over a wide spectrum of body sizes (Table L). The most abundant zooplankter was the small rotifer *Keratella*. Potential predators in the zooplankton community include the large-bodied calanoid copepods and the cladoceran *Polyphemus pediculus*, both of which were common.

Polyphemus pediculus is a widely distributed species in lakes and ponds that can be especially abundant in late summer when it feeds primarily on rotifers, such as *Keratella* (Bosak 2013).

Table L. Summary of Zooplankton Results at Grassy Pond

Taxon	Relative Abundance	Size
Bosmina longirostris	Rare	Small
Calanoid copepods	Common	Large
Cyclopoid copepods	Rare	Small
Copepod nauplii	Rare	Small
Keratella	Abundant	Small
Polyphemus pediculus	Common	Small

Old Mill/Graniteville Pond

Water Quality

Old Mill/Graniteville Pond is a 15-acre pond that is approximately 5 m deep at its deepest point, which is located near the dam at the northern end of the north basin. Dissolved oxygen concentrations at Old Mill/Graniteville Pond were high during the spring sampling event (Table M). During the summer sampling event, dissolved oxygen concentrations were adequate at two locations but below the state standard of 5.0 mg/L at one location (OLD-C). Old Mill/Graniteville Pond was anoxic at the pond bottom during the spring sampling event, and this zone of minimal dissolved

Old Mill/Graniteville Pond is shallow and narrow.

oxygen had expanded to include the bottom 3 m during the summer sampling event (Figure C). Specific conductance values were very high during both the spring and summer sampling events, indicating a high content of dissolved salts, although these may be naturally occurring. Turbidity values were low, and pH values were good at all locations during both sampling events. Secchi disk readings were generally acceptable at all locations during both sampling events.

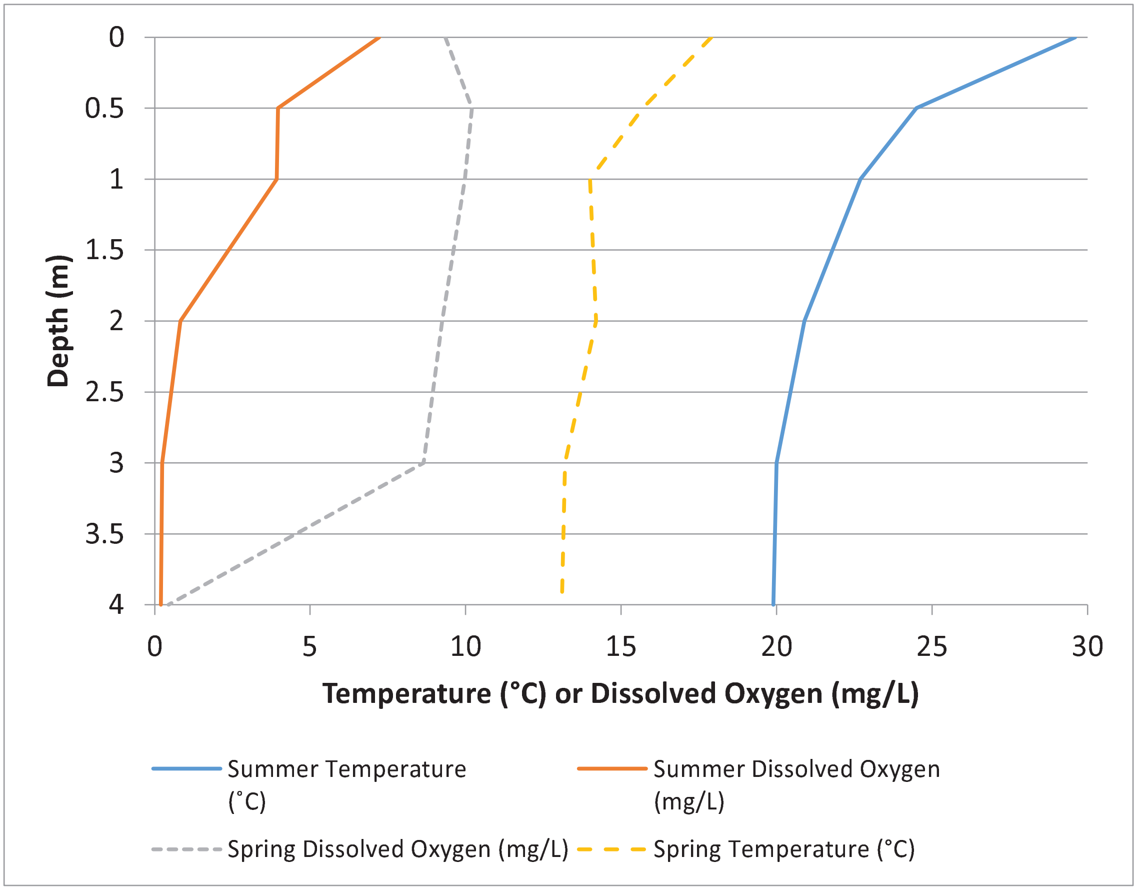

Figure C. Temperature and Dissolved Oxygen Profile at Old Mill/Graniteville Pond

Dissolved inorganic nitrogen (ammonia and nitrate) in surface waters of Old Mill/Graniteville Pond were the highest of the five ponds studied (Table M). This could potentially indicate an impact from septic systems in the area. Phosphorus levels, however, were generally in an acceptable range, rarely exceeding 0.02 mg/L.

Table M. Water Quality Results at Old Mill/Graniteville Pond

Site ID		OLD-A	OLD-B	OLD-C
Date	Spring	5/8/2014	5/8/2014	5/8/2014
	Summer	8/6/2014	8/6/2014	8/6/2014
Time	Spring	13:15	13:30	12:55
	Summer	13:17	13:07	11:17
Temperature (°C)	Spring	17.9	17.8	17.5
	Summer	29.6	28.6	25.8
Dissolved Oxygen (mg/L)	Spring	9.35	10.88	11.6

Site ID		OLD-A	OLD-B	OLD-C
	Summer	7.22	6.10	4.23
Dissolved Oxygen (%)	Spring	98	110.1	121
	Summer	88.2	74.4	50.8
Specific Conductance (µS/cm)	Spring	552	548	551
	Summer	575	581	583
pH (SU)	Spring	7.22	7.23	7.3
	Summer	7.66	7.58	7.11
Turbidity (NTU)	Spring	2.99	0.79	4.3
	Summer	1.10	0.83	0.2
Secchi Depth (m)	Spring	2.7	Bottom	Bottom
	Summer	2.5	2.5	Bottom
Total Depth (m)	Spring	4.6	3.0	0.6
	Summer	5.0	3.0	1.0
Ammonia (mg/L)	Spring	0.47	0.097	0.098
	Summer	0.055	0.067	0.12
Nitrate (mg/L)	Spring	0.21	0.19	0.18
	Summer	0.12	0.16	0.17
Total Phosphorus (mg/L) (Surface)	Spring	0.012	0.017	0.013
	Summer	0.019	0.017	0.020
Total Phosphorus (mg/L) (Bottom)	Spring	-	-	-
	Summer	0.021	-	-
Chlorophyll-*a* (mg/m3)	Spring	8.92	-	-
	Summer	4.2	-	-

ND = Non-detect. Analyte concentration did not exceed laboratory detection limit.

Aquatic Plants

Eighteen species of aquatic plants were observed at Old Mill/Graniteville Pond, making it the most taxonomically rich of the five study ponds (Table N). However, Old Mill/Graniteville Pond was also the only waterbody included in the study in which more than one aquatic invasive plant species was detected. The most prevalent of these by far was fanwort (*Cabomba caroliniana*), which covered 12.5 acres and was very dense over much of the pond. Fanwort occupied the entirety of the shallow southern basin leaving very little open water. It was also widespread in the northern basin, absent only at a few deeper areas near the middle of the pond. Variable-leaf milfoil was also detected at Old Mill/Graniteville Pond; however, it was growing sparsely at a few non-contiguous locations. Similarly, growth of exotic curly-leaf pondweed (*Potamogeton crispus*) was also sparse and found only at a few non-contiguous locations in the pond. Both variable-leaf milfoil and curly-leaf pondweed can form dense stands in ponds where they have invaded. However, the very dense infestation of fanwort in Old Mill/Graniteville Pond is likely outcompeting these species and preventing them from expanding.

Plant cover was very high throughout most of Old Mill/Graniteville Pond, but was lower in the deeper waters near the center of the northern basin. Due to the relatively deep waters throughout the pond and especially in the northern basin, plant biovolume was somewhat lower than plant cover in most areas of the pond away from shore.

Table N. Aquatic Plants Observed at Old Mill/Graniteville Pond

Common Name	Scientific Name	Native or Exotic
Fanwort	*Cabomba caroliniana*	Exotic
Water Starwort	*Callitriche heterophylla*	Native
Coontail	*Ceratophyllum demersum*	Native
Spikerush	*Eleocharis sp.*	Native
Canadian waterweed	*Elodea canadensis*	Native
Duckweed	*Lemna sp.*	Native
Marsh Seedbox	*Ludwigia palustris*	Native
Variable-leaf Milfoil	*Myriophyllum heterophyllum*	Exotic
Bushy Naiad	*Najas flexilis*	Native
Yellow Water Lily	*Nuphar lutea variegata*	Native
White Water Lily	*Nymphaea odorata*	Native
Curly-leaf Pondweed	*Potamogeton crispus*	Exotic
Floating-leaf Pondweed	*Potamogeton epihydrus*	Native
Longleaf Pondweed	*Potamogeton nodosus*	Native
Robbins' Pondweed	*Potamogeton robbinsii*	Native
Spiral Pondweed	*Potamogeton spirillus*	Native
Common Bladderwort	*Utricularia macrorhiza*	Native
Water Celery	*Vallisneria americana*	Native

Phytoplankton and Zooplankton

Phytoplankton

Phytoplankton growth in Old Mill/Graniteville Pond was not particularly dense, and only a few taxa were documented from the summer sample (Table O). *Synura* was one of the most common taxa encountered, although the large dinoflagellate *Ceratium* was also found. *Aphanothece* belongs to the cyanobacteria and is another genus known to produce toxins under certain population and environmental conditions (Quiblier et al. 2013).

Table O. Summary of Phytoplankton Results at Old Mill/Graniteville Pond

Type	Taxon	Abundance
Cyanobacteria	*Aphanothece*	rare
Diatom	Various benthic species	rare
Dinoflagellate	*Ceratium*	rare
Synurophytes	*Synura*	common

Zooplankton

The zooplankton density in Old Mill/Graniteville Pond was high and the community was characterized by small to medium-bodied taxa (Table P). The most abundant zooplankter was the cladoceran *Holopedium gibberum*, a grazing species that is able to effectively compete for limited phytoplankton food resources (Balcer et al. 1984), such as those encountered at Old Mill/Graniteville Pond. Other species, including copepods, other cladocerans, and rotifers were also present but in much lower abundances

Table P. Summary of Zooplankton Results at Old Mill/Graniteville Pond

Taxon	Relative Abundance	Size
Bosmina longirostris	Rare	Small
Chydoridae	Rare	Medium
Cyclopoid copepods	Rare	Small
Copepod nauplii	Rare	Small
Diaphanosoma	Rare	Medium
Holopedium gibberum	Abundant	Medium
Keratella	Rare	Small

Kennedy Pond

Water Quality

Kennedy Pond is not large but its bowl shape, open waters and natural shoreline create a majestic setting.

Kennedy Pond is a 17-acre pond that is approximately 10 m deep at its deepest point, which is located in the western part of the pond. Dissolved oxygen concentrations were above state standards at the surface during both sampling events (Table Q). However, dissolved oxygen fell below state standards in the hypolimnion at depths of 6 m to 7 m (Figure D). Specific conductance values were not outside of the expected range at any of the sampling locations. Furthermore, turbidity values were low, and pH values were well within acceptable parameters at all locations during both sampling events. The Secchi disk was visible on the bottom at location KEN-B during both events and more than 3 m at location KEN-A. Chlorophyll *a* concentrations were marginally elevated during the spring sampling event but low during the summer sampling event.

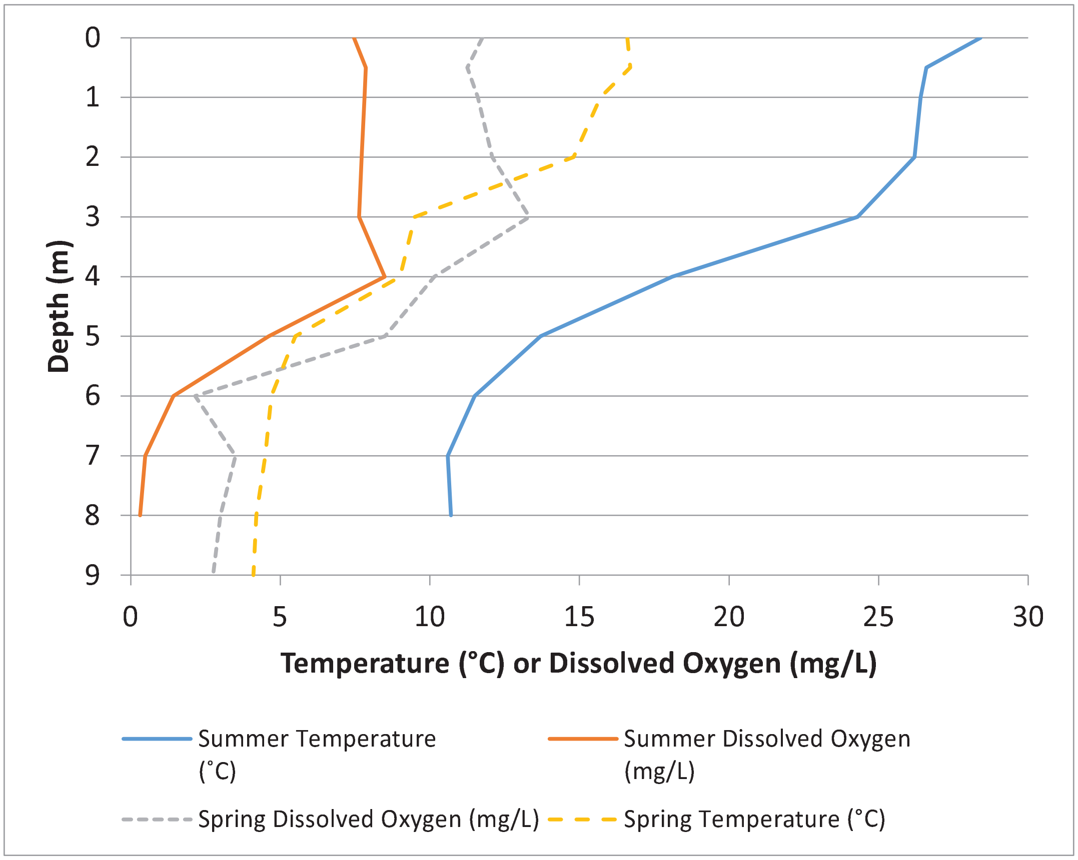

Figure D. Temperature and Dissolved Oxygen Profile at Kennedy Pond

Neither dissolved inorganic nitrogen (ammonia and nitrate) nor phosphorus levels appeared to be elevated in Kennedy Pond (Table Q). In fact, phosphorus concentrations were the lowest measured of the five ponds included in this study.

Table Q. Water Quality at Kennedy Pond

Site ID		KEN-A	KEN-B
Date	Spring	5/8/2014	5/8/2014
	Summer	8/7/2014	8/7/2014
Time	Spring	11:45	12:05
	Summer	13:45	13:35
Temperature (°C)	Spring	16.6	17.3
	Summer	28.4	28.4
Dissolved Oxygen (mg/L)	Spring	11.75	11.5
	Summer	7.46	8.21
Dissolved Oxygen (%)	Spring	117.3	116.9
	Summer	96.4	102.6
Specific Conductance (µS/cm)	Spring	149	145.9
	Summer	153.8	153.8
pH (SU)	Spring	7.5	7.63

	Summer	8.26	8.6
Turbidity (NTU)	**Spring**	0.02	0.55
	Summer	1.17	0.83
Secchi Depth (m)	**Spring**	4.9	Bottom
	Summer	3.25	Bottom
Total Depth (m)	**Spring**	9.1	1.8
	Summer	9.0	1.25
Ammonia (mg/L)	**Spring**	0.12	0.29
	Summer	ND	ND
Nitrate (mg/L)	**Spring**	ND	ND
	Summer	ND	ND
Total Phosphorus (mg/L) (Surface)	**Spring**	ND	0.012
	Summer	ND	ND
Total Phosphorus (mg/L) (Bottom)	**Spring**	-	-
	Summer	0.014	-
Chlorophyll-*a* (mg/m3)	**Spring**	9.21	-
	Summer	2.7	-

ND = Non-detect. Analyte concentration did not exceed laboratory detection limit.

Aquatic Plants

Eight species of aquatic plants were documented at Kennedy Pond (Table R), and it was found to be free of submergent and floating exotic plant species, although there was some limited growth of emergent common reed and purple loosestrife along the shoreline of the pond. Similar to Grassy Pond, the lack of any perennial tributaries to Kennedy Pond may in part explain the absence of invasive aquatic plants. The lack of a formal boat ramp or access to the pond via automobile is likely also significant. Aquatic invasive plant species are often transported from a pond with an established population of the plant to a "clean" pond by becoming attached to boats or boat motors. Kennedy Pond offers no public access and has no access for watercraft larger than a canoe or kayak, which likely benefits the pond with regard to being maintained free of aquatic invasive species.

Plant cover was relatively low in most of Kennedy Pond but locally dense along the northwestern and southwestern shorelines of the pond. Plant biovolume was low throughout the pond, due in part to the relatively high water depths near the center of the pond and to the sandy substrate around the exposed shoreline of the pond, which is not as conducive to the growth of tall plants as the protected mucky substrates found in other ponds.

Table R. Aquatic Plants Observed at Kennedy Pond

Common Name	Scientific Name	Native or Exotic
Waterwort	*Elatine sp.*	Native
Spikerush	*Eleocharis sp.*	Native
Golden Hedge-hyssop	*Gratiola aurea*	Native
Quillwort	*Isoetes sp.*	Native
Bushy Naiad	*Najas flexilis*	Native
Stonewort	*Nitella sp.*	Native
Clasping-leaf Pondweed	*Potamogeton perfoliatus*	Native

Common Name	Scientific Name	Native or Exotic
Thinleaf Pondweed	*Potamogeton pusillus*	Native

Phytoplankton and Zooplankton

Phytoplankton

The phytoplankton community at Kennedy Pond was characterized by low overall abundance, with the dinoflagellate *Glenodinium* and the green alga *Chlamydomonas* most common. (Table S). The synurophyte *Synura* and the cyanobacterium *Chroococcus* were also both present but rare. *Chroococcus*, which is known to produce toxins under certain population and environmental conditions, was not present at bloom levels in Kennedy Pond.

Table S. Summary of Phytoplankton Results at Kennedy Pond

Type	Taxon	Abundance
Dinoflagellate	*Glenodinium*	common
Green	*Chlamydomonas*	common
Cyanobacteria	*Chroococcus*	rare
Synurophytes	*Synura*	rare
Various	Other flagellates	rare

Zooplankton

The zooplankton community was characterized by moderate abundance of small- to large-bodied individuals from multiple taxa (Table T). The cladoceran *Holopedium gibberum* and the rotifer *Kellicottia longispina* were co-dominant species. Large-bodied calanoid copepods were also found in abundance. The cladoceran *Daphnia* was found at low densities as well.

As mentioned previously, *Holopedium gibberum* is a highly efficient grazer at low phytoplankton densities (such as those observed in Kennedy Pond) and may dominate the zooplankton community under these conditions (Balcer et al. 1984).

Table T. Summary of Zooplankton Results at Kennedy Pond

Taxon	Relative Abundance	Size
Bosmina longirostris	Rare	Small
Calanoid copepods	Common	Large
Copepod nauplii	Common	Small
Daphnia sp.	Rare	Large
Holopedium gibberum	Abundant	Medium
Kellicottia longispina	Abundant	Small

Summary of Overall Pond Conditions

Pond conditions were classified based on water quality and invasive species (plants) and overall condition of the pond. The four water quality classes were determined as follows:

1. Excellent – No negative factors
2. Good – One negative factor but no severe problems
3. Fair – Multiple negative factors but no severe problems

4. Poor – Multiple negative factors and at least one severe problem

Likewise, the four invasive species classes were determined as follows:

1. Excellent – No invasive species observed
2. Good – No aquatic invasive species established, although one or more shoreline invasives may be present
3. Fair – Aquatic invasive species established but do not occupy majority of the water body. One or more shoreline invasives may also be present.
4. Poor – Aquatic invasive species established and dominant over a majority of the water body. One or more shoreline invasives may also be present.

A summary of the condition of each previously unstudied pond is presented in Table U.

Table U. Summary of Pond Condition

Pond	Water Quality		Invasive Species		Overall Condition
	Condition	Factors Impacting Condition	Condition	Factors Impacting Condition	
Keyes Pond	Fair	• Summer Clarity • Excessive Algae • Hypolimnetic Dissolved Oxygen • Hypolimnetic Phosphorus • Tributary Dissolved Oxygen	Fair	• Variable-leaf milfoil dominant • Purple loosestrife and common reed along shoreline	Fair
Burge's Pond	Fair	• Hypolimnetic Dissolved Oxygen • Phosphorus	Fair	• Variable-leaf milfoil dominant	Fair
Grassy Pond	Fair	• Summer Dissolved Oxygen • Phosphorus • Dissolved Inorganic Nitrogen • Turbidity	Excellent	• None	Good
Old Mill/Graniteville Pond	Fair	• Summer Dissolved Oxygen (part) • Dissolved Inorganic Nitrogen	Poor	• Fanwort dominant • Variable-leaf milfoil present • Curly-leaf pondweed present • Purple loosestrife and common reed along shoreline	Fair

Pond	Water Quality		Invasive Species		Overall
Kennedy Pond	Excellent	• None	Good	• Purple loosestrife and common reed along shoreline	Good

SUMMARY OF INFORMATION ON PREVIOUSLY STUDIED PONDS

Long Sought for Pond

Herbicide treatments (Sonar) for the control of Eurasian watermilfoil (*Myriophyllum spicatum*) were conducted at Long Sought for Pond in 2004. Since 2005, aquatic vegetation and water quality surveys have been conducted annually. The aquatic plant survey in 2005 revealed that very little milfoil had persisted, however, curly-leaf pondweed was notably abundant in the pond. Hand-harvesting of milfoil was employed on an as-needed basis, while spot-treatment of curly-leaf pondweed (Reward herbicide) was conducted in 2006, 2007, and 2009, which appeared to effectively control its growth. Herbicide treatments were not required or conducted in 2008 or after 2009. Aquatic Control Technology, Inc. (ACT) conducts early-season monitoring surveys to identify the need for herbicide treatments each year.

There was evidence of trout mortality in the mid-summer observed in 2010 and 2011, possibly due to lack of cold water habitat at that time. The extreme temperatures that caused the water to warm also led to depleted oxygen levels. Less-severe temperatures and subsequent oxygen depletion in 2012 correlated with lower trout mortality.

There was some evidence of cyanobacteria in the pond in 2011 and 2012, albeit at low levels. Moderate algal bloom conditions (green and cyanobacteria) were observed again in 2013.

The most recent report (2013) recommends continuation of early and late summer plant surveys and three rounds of water quality sampling. The authors did not speculate that herbicide treatment would be required in 2014 or beyond. However, there may be a need to conduct copper-based algaecide treatments to control filamentous green algae and cyanobacteria growth.

The water quality monitoring recommendations in the 2013 report include hypolimnetic testing, particularly to continue data collection related to the trout mortality in 2010 and 2011. These data are necessary to assess the need for more complex and costly remediation of the oxygen depletion issues.

A summary of monitoring and management actions at Long Sought for Pond from 2004 to 2013 is presented in Table V.

Table V. Documented Monitoring and Management Actions at Long Sought for Pond

Action	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Water Quality Sampling		X	X	X	X	X	X	X	X	X
Plant Surveys		X	X	X	X	X	X	X	X	X
Bathymetry Survey										
Macroinvertebrate/ Mussel Survey										
Shoreline Erosion Monitoring										
Herbicide Application (Sonar)	X									
Herbicide Application (Diquat)			X	X		X				
Mechanical/Hand-Harvest		X								
Drawdown										

Nabnasset Lake

The nuisance vegetation targeted in the lake includes variable-leaf milfoil and curly-leaf pondweed since 2001 and brittle naiad (*Najas minor*) since 2009. Since 2002, the vegetation management program has been guided by the results of targeted monitoring that tracks plant growth, the populations of non-target species, water quality, and erosion. The primary management actions used to address excessive exotic vegetation in the pond have included winter drawdown, spot herbicide (diquat) treatments, and limited harvesting. The combined management program appears to be providing consistently effective control of variable-leaf milfoil, which spreads primarily through fragmentation while having no significant impact on non-target organisms such as freshwater mussels, emergent wetland plants. and other aquatic invertebrates.

Variable-leaf milfoil was no longer detected during annual in-lake monitoring in 2013 or 2014. However, curly-leaf pondweed and brittle naiad beds have been controlled primarily through spot treatments with herbicides because they reproduce through seeds or winter turions, which makes drawdown less effective as a control method for these species.

The emergent exotic plant, purple loosestrife, is also present in the shallow western end of Nabnasset Lake (Shipley Swamp), but the monitoring program has not detected an expansion in its growth since the winter drawdown program began. Adult loosestrife beetles have been observed feeding on purple loosestrife plants in Shipley Swamp. It is not known how the beetles were introduced to the site, but it is possible that they may be at least partially responsible for the control of this species.

A potentially harmful cyanobacteria bloom in late 2012 briefly closed the pond to swimming. No bloom was reported in 2013. However, in 2014, the pond was treated with a copper-based algaecide based on an observed increase in water column cyanobacteria cells (although not to bloom densities). The algaecide treatment was undertaken as a preventative measure to preclude the full development of a cyanobacteria bloom. The cause of the blooms has not yet been established. Typically, rising phosphorus concentrations (or falling nitrogen levels) and favorable weather conditions are associated with cyanobacteria blooms. However, no consistent increase in phosphorus has been observed in Nabnasset Lake since annual monitoring began.

A summary of monitoring and management actions at Nabnasset Lake from 2001 to 2014 is presented in Table W.

Table W. Documented Monitoring and Management Actions at Nabnasset Lake

Action	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11	'12	'13	'14
Water Quality Sampling	X	X		X	X		X	X	X		X	X	X	X
Plant Surveys	X	X	X	X			X	X	X	X	X	X	X	X
Bathymetry Survey		X												
Macroinvertebrate/ Mussel Survey		X		X				X	X		X	X	X	X
Erosion Monitoring									X		X	X	X	X
Herbicide Application (Fluridone)														
Herbicide Application (Diquat)					X	X	X		X	X	X	X		X
Mechanical/Hand Harvest*														
Winter Drawdown			X			X			X		X	X		

*Occasional hand harvesting has irregularly occurred, typically on a small scale around docks and shorelines

Forge Pond

A drawdown of Forge Pond was initiated in October 2007 and ended in February 2008. Aquatic vegetation monitoring was conducted during the summer before (July 2007) and summer after (August 2008) the drawdown period. Twenty-six macrophyte species were observed in July 2007, six of which were non-native. In 2008, twenty-eight macrophyte species were observed, four of which were non-native. Plant density was slightly lowered in 2008 following the drawdown, with 47% of sites still harboring dense or very dense plant growth compared to 53% in 2007. Fanwort, variable-leaf milfoil, Eurasian watermilfoil, and water chestnut (*Trapa natans*) were present during both survey years. The drawdown had a seemingly minor impact on control of the submerged species, while hand-harvesting was used as a control effort in 2007 and 2008 on water chestnut. Both brittle naiad and curly-leaf pondweed were observed in small quantities during the 2007 survey but were not detected in 2008.

Wetland monitoring at three sites suggested no major impacts of the drawdown to the wetland habitat. Plot assemblages before and after drawdown were similar, although the water table was higher at each plot in 2008.

A freshwater mussel survey was conducted along five 30-meter transects running parallel to shore in approximately 2-ft depth intervals. Mussels along the transect length were collected using a clam rake to a depth of 10 cm over a 0.5 m wide swath. The only mussel identified during the surveys before (August 2007) and after (August 2008) drawdown were eastern elliptio (*Elliptio complanata*), the most abundant and widespread mussel in the region. Mussels were significantly less abundant in 2008 versus 2007, during which time they declined from 183 specimens to 48.

Monitoring for other invertebrates was conducted via kick-net surveys at 15 monitoring locations, before (August 2007) and after (August 2008) drawdown. A greater number of invertebrate specimens was collected in 2008 (484) compared to 2007 (366). This increase was seen primarily in the total count of Amphipoda (amphipods), Diptera (true flies), and Ephemeroptera (mayflies). In 2007, the most abundant taxa were Amphipoda, Coleoptera (beetles), Ephemeroptera, and Diptera. In 2008, the most abundant taxa were Amphipoda, Diptera, Ephemeroptera, and Odonata (dragonflies and damselflies). Species composition at each site varied between the years.

Water quality results were also presented for sampling conducted during and after the drawdown. However, no thorough discussion of results or recommendations for further management was made. The 2008 post-drawdown summary report was the only readily available monitoring and management document for Forge Pond.

A summary of monitoring and management actions at Forge Pond since 2007 is presented in Table X.

Table X. Documented Monitoring and Management Actions at Forge Pond

Action	2007	2008	2009	2010	2011	2012	2013	2014
Water Quality Sampling		X						
Plant Surveys	X	X						
Bathymetry Survey								
Macroinvert/Mussel Survey	X	X						
Erosion Monitoring								
Herbicide Application (Sonar)								
Herbicide Application (Diquat)								
Mechanical/Hand-Harvest								
Drawdown	X							X*

*Plans for winter drawdown were communicated at November 18, 2014 Healthy Lakes and Ponds Collaborative Meeting

Heart Pond

A baseline study of Heart Pond was conducted in 2004 in response to the Heart Pond Association's desire to take management action against nuisance fanwort growth in the pond. In 2005, ACT began SONAR AS (fluoridone) treatments within the pond. Post-treatment inspections beginning in September revealed greater than 90% control of fanwort was achieved and native plants had persisted. It was recommended that continued early and late-season plant surveys be conducted the following year to monitor the pond, as well as for the Association to budget for a whole-pond algaecide treatment to combat algae growth in the next year.

ACT conducted a survey of the aquatic plant community again in August 2010 in response to growing concerns regarding the plant growth within the pond. The survey revealed 3 invasive species – fanwort, curly-leaf pondweed, and purple loosestrife. ACT recommended small-scale management options for native and invasive plant species control, as well as algae control for the pond. They permitted and implemented management strategies in 2011, including spot-treatment using Reward (diquat) herbicide on curly-leaf pondweed, coontail, and waterweed and diver hand-pulling of fanwort in areas of dense growth. There was little evidence of algal blooms during the early summer herbicide treatment period, however, microscopic and filamentous algae was present during the autumn diver activities. Curly-leaf pondweed and the target native species appeared to be effectively controlled by the herbicide treatment, and the remaining plant assemblage was believed to provide desirable habitat and pose minimal threat to recreational uses of the pond. Fanwort growth was still expected to be problematic, and further monitoring and management was recommended.

Spot treatments using the herbicide Reward were used to repeat the management efforts of 2011 to control nuisance growth of curly-leaf pondweed, coontail, and waterweed in 2013. Herbicide treatment of approximately 10 acres was conducted in June, followed by post-treatment inspection in July. Once again, control of the targeted species was achieved with this spot treatment and a desirable plant assemblage remained, maintaining aquatic habitat in the pond. Fanwort growth was observed to have expanded since the previous diver hand-pulling control efforts; however, it was still deemed to be at non-problematic densities.

ACT recommended continuation of Reward treatment in 2014 and indicated that the dosage may be reduced due to the effective management of the targeted plant growth in the previous years.

Fanwort growth was mapped again in Heart Pond in 2014. Although the majority of the shoreline hosted only scattered fanwort growth, high-density beds were found in multiple locations. The most widespread of these high-density beds were located at the western end of the pond and, to a lesser extent, in southern and northeastern coves.

A summary of monitoring and management actions at Heart Pond from 2005 to 2014 is presented in Table Y.

Table Y. Documented Monitoring and Management Actions at Heart Pond

Action	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Water Quality Sampling	X					X		X	X	
Plant Surveys	X					X	X		X	X
Bathymetry Survey										
Macroinvert/Mussel Survey										
Erosion Monitoring										
Herbicide Application (Sonar)	X									
Herbicide Application (Diquat)							X		X	

Mechanical/Hand-Harvest							X			
Drawdown										

RECOMMENDATIONS

Prioritization for Action

The need for active management to address water quality or invasive vegetation issues is more urgent at some ponds than others. In general, the ponds with more impacted water quality or biology are in need of more immediate attention to restore water quality and aquatic habitat, particularly if they are important recreational resources. Each of the previously unstudied ponds is prioritized in Table Z.

Table Z. Prioritization of Town Lakes and Ponds for Management Action

Priority	Pond	Reasoning	Potential Consequences of Inaction
1	Keyes	• Water quality was poorest of the previously unstudied ponds • Cyanobacteria bloom observed (these are a potential public health risk) • Adjacent residents and recreational use	• Recurrence of potentially harmful algae blooms • Accelerating degradation of water quality • Reduced recreational value • Reduced aquatic habitat value
2	Burge's	• Water quality among poorest of the previously unstudied ponds • Likely receives greatest amount of recreational use (including swimming) among the previously unstudied ponds • Aquatic invasive vegetation is widespread – undesirable near swimming beaches	• Accelerating degradation of water quality • Reduced recreational value • Reduced aquatic habitat value
3	Old Mill/Graniteville	• Aquatic vegetation was in poorest condition of the previously unstudied ponds • Room for water quality improvement	• Accelerating degradation of water quality • Reduced aquatic habitat value
4	Kennedy	• Excellent water quality • Some shoreline invasives present but the infestations are minor and could be effectively controlled • Good recreational opportunity	• Persistence or expansion of shoreline invasives • Otherwise, no immediate threats identified • However, monitoring still recommended so that threats can be identified and cost-effectively addressed at an early stage
5	Grassy	• Apparent water quality issues are probably related to the natural shallowness of the pond – it functions more like an emergent wetland • Aquatic invasive vegetation does not currently appear to be a problem • Minor recreational value	• No immediate threats identified • However, monitoring still recommended so that threats can be identified and cost-effectively addressed at an early stage

All of the previously studied ponds host a large number of year-round residents, are important recreational resources, and clearly have management issues that require and are receiving ongoing attention. Among these, Long Sought-for Pond is the only pond upstream of another in-town pond (Keyes Pond). Therefore, issues impacting Long Sought-for Pond are also likely to have an impact on Keyes Pond, and some additional coordination of efforts would be beneficial to maximize the opportunity for successful management.

The ponds that have experienced recurring algae blooms or hypolimnetic dissolved oxygen depletion, including Long Sought-for Pond, Nabnasset Lake, and Heart Pond, would benefit from an updated nutrient budget study to quantify the sources and target the most cost-effective source reduction actions at each pond. Such a study could be completed for $5,000 to $10,000, depending on scope of the potential nutrient sources.

Monitoring Program

With the Town's goals for this study in mind, future monitoring at each pond is recommended on at least an annual basis to gather long-term water quality data, document trends that may be observed (either positive or negative), closely monitor the expansion or contraction of invasive weed beds, and quickly identify pioneer infestations of any new invasive species.

The monitoring programs at each of the previously studied ponds have been tailored to meet the management needs of those water bodies. Therefore, no significant changes to those monitoring programs are recommended at this time.

However, a standard monitoring program should be adopted for each of the Town's previously unstudied ponds that includes the following elements:

Water Quality – At least one in-pond sampling location with surface and bottom samples collected. A vertical profile (at 0.5 to 1.0 m intervals) of temperature and dissolved oxygen should be measured at this location. Tributary and outlet samples should also be collected on the same day, where applicable. If Westford Stream Team monitoring locations are present upstream or downstream, it may be possible to coordinate the timing of sampling. This would have the benefit of providing a more complete snapshot of system conditions at the time. The recommended minimum water quality monitoring parameters are presented in Table AA.

Table AA. Recommended Minimum Water Quality Monitoring Parameters

Parameter	In-pond at Deep Hole	Tributaries and Outlets
Water Temperature	Vertical profile every 0.5 to 1.0 meters from surface to bottom.	Single in-stream reading
Dissolved Oxygen	Vertical profile every 0.5 to 1.0 meters from surface to bottom.	Single in-stream reading
Specific Conductance	Surface and bottom	Single in-stream reading
pH	Surface and bottom	Single in-stream reading
Turbidity	Surface and bottom	Single in-stream reading
Secchi Depth	Average of at least two readings from surface	N/A
TKN	Surface and bottom	Single in-stream reading
Ammonia	Surface and bottom	Single in-stream reading
Nitrite –Nitrate	Surface and bottom	Single in-stream reading
Total Phosphorus	Surface and bottom	Single in-stream reading
Dissolved Phosphorus	Surface and bottom	Single in-stream reading
Discharge	N/A	Single in-stream cross-section

Aquatic Vegetation – Survey should include identification of species in the plant community and measurement of vegetative cover and biovolume. Special attention should be given to quantifying the intensity and extent of any exotic species infestations.

Plankton – At least one representative in-pond sample analyzed for species composition and density or abundance of organisms. The sample should be depth-integrated to include the entire water column from the surface to at least the Secchi disk depth.

Professional Evaluation of Condition – Data should be professionally reviewed by a Certified Lake Manager to evaluate the condition of the pond, assess trends, and update recommendations for monitoring and management.

Bathymetry – Water depths in the pond should be mapped and contoured, and the total volume should be calculated.

Nutrient Budget – Model phosphorus and nitrogen budgets to assess trophic status of the pond, identify primary sources of nutrients, and establish targets for reduction of nutrient loading, if necessary. Modeling can also be used to examine the impact of future development scenarios on water quality in the pond.

Erosion – Assess condition of trails and shorelines, identify areas of significant erosion, and select measures to control or eliminate ongoing erosion.

The recommended monitoring timeline is presented in Table AB.

Table AB. Recommended Timeline for Monitoring

Monitoring Element	Best Time*	2015	2016	2017	2018	2019	Thereafter**
Full Suite of Water Quality Parameters	July or August						Annually
Aquatic Vegetation	July or August						Annually
Zooplankton/ Phytoplankton	July or August						Annually
Professional Evaluation of Pond Condition (Report Card or Trend Analysis)	Summer/Early Fall						Annually
Bathymetry	Anytime						Every 10 years
Nutrient Budget	Anytime						Every 5 to 10 years
Erosion (Trails and Shoreline Condition)	Spring or Fall						Every 5 years or as recommended in trail management plan

*Assumes monitoring is completed at the minimum recommended frequency.
**Minimum recommended frequency. May need to adjust frequency if significant changes in pond condition are observed or suspected.

Volunteer monitoring efforts are also encouraged and may be integrated into the monitoring program for each pond. The Massachusetts Weed Watchers program (sponsored by the Department of Conservation and Recreation's Lakes and Ponds Program) provides some training and support for volunteers interested in monitoring aquatic plants. The Westford Stream Team has monitored local streams since 2005 and provides training and support for volunteers interested in monitoring water quality.

Management

Based on our brief and limited inspection of the ponds in this study, it is clear that some efforts will be required to maintain and/or improve conditions at these ponds.

Beyond monitoring, there are several actions for the Town to consider that may be beneficial toward addressing identified issues related to degraded water quality and existing beds of invasive weeds. In many cases, there are multiple options that could be selected to preserve or improve the ponds.

A summary of the primary options for each pond is presented in Table AC. A prioritized five-year timeline for the currently recommended options is available in Appendix B.

Table AC. Summary of Options for Previously Unstudied Ponds

Option	Description	Additional Information	Recommendation by Pond with Cost Estimate				
			Keyes	Burge's	Grassy	Old Mill/ Graniteville	Kennedy
Monitoring*	Annual monitoring to provide early detection of invasive species and document water quality and overall ecological condition.	Additional monitoring may be required to meet permit-specific conditions for any management actions	$3,500 to $4,500/year	$3,500 to $4,500/year	$3,500 to $4,500/year	$3,500 to $4,500/year	$3,500 to $4,500/year
Chemical Treatment of Nuisance Plants	Design/Permitting*	Additional studies and required permits	Local NOI $6,000 to $8,000	Local NOI $6,000 to $8,000	NR (Not Recommended)	Local NOI $6,000 to $8,000	NR
	Implementation	Systemic - Fluridone (Sonar) $800 to $1,000/acre	NR	NR	NR	$12,000 to $15,000 for full lake treatment	NR
		Systemic – 2,4-D (Navigate) $500 to $600/acre	$21,000 to $26,000 for full lake treatment	$13,500 to $16,200 for full lake treatment	NR	NR	NR
		Contact – Flumioxazin (Clipper) $900 to $1,100/acre	NR	NR	NR	$2,000 to $3,000/year	NR
		Contact – Diquat (Reward) $200 to $400/acre	$4,000 to $5,000/year	$3,000 to $4,000/year	NR	$2,000 to $3,000/year	NR
	Post-implementation	Additional monitoring may be required specific to permit conditions	Varies	Varies	NR	Varies	NR
Chemical Treatment of Nuisance Algae	Design/Permitting*	Additional studies and required permits	Local NOI $6,000 to $8,000	NR	NR	NR	NR

Option	Description	Additional Information	Recommendation by Pond with Cost Estimate				
			Keyes	Burge's	Grassy	Old Mill/ Graniteville	Kennedy
	Implementation	Copper-based algaecide or low-dose alum $300 to $800/acre	Varies depending on approach and frequency/ extent of algae bloom. However, $2,000 to $8,000/year would be the expected range.	NR	NR	NR	NR
	Post-implementation	Monitoring to ensure algae have been effectively treated	Varies	NR	NR	NR	NR
Harvesting of Nuisance Plants	Design/Permitting*	Additional studies and required permits	Local NOI $6,000 to $8,000	NR	Local NOI $6,000 to $8,000	Local NOI $6,000 to $8,000	Local NOI $6,000 to $8,000
	Implementation	Hand Harvesting	Can be done by trained volunteers	NR	Can be done by trained volunteers	Can be done by trained volunteers	Can be done by trained volunteers
		Diver Assisted Suction Harvesting $2,500 to $6,000/acre	NR for entire pond – use acre-based cost estimate for small areas (5 acres or less)	NR	NR for entire pond – use acre-based cost estimate for small areas (5 acres or less)	NR for entire pond – use acre-based cost estimate for small areas (5 acres or less)	NR for entire pond – use acre-based cost estimate for small areas (5 acres or less)
		Mechanical Harvesting	NR	NR	NR	NR	NR
	Post-implementation	Additional monitoring may be required specific to permit conditions	Varies	Varies	NR	Varies	NR
Hydroraking of Nuisance Plants	Design/Permitting*	Additional studies and required permits	NR - Local NOI $6,000 to $8,000	NR - Local NOI $6,000 to $8,000	NR - Local NOI $6,000 to $8,000	NR - Local NOI $6,000 to $8,000	NR - Local NOI $6,000 to $8,000
	Implementation	$6,000 to $12,000/acre	NR	NR	NR	NR	NR
	Post-implementation	Additional monitoring may be required specific to permit conditions	NR	NR	NR	NR	NR

Option	Description	Additional Information	Recommendation by Pond with Cost Estimate				
			Keyes	Burge's	Grassy	Old Mill/ Graniteville	Kennedy
Biological Controls of Nuisance Plants	Design/Permitting*	Loosestrife Beetles	Obtain organisms from permitted source	Obtain organisms from permitted source	NR – works best over contiguous beds	Obtain organisms from permitted source	NR – works best over contiguous beds
	Implementation	Loosestrife Beetles	$300 to $600/year	$300 to $600/year	NR	$300 to $600/year	NR
	Post-implementation	Loosestrife Beetles	$2,000/year to monitor and plan for subsequent year	$2,000/year to monitor and plan for subsequent year	NR	$2,000/year to monitor and plan for subsequent year	NR
Water Level Control (Drawdown)	Design/Permitting*	Additional studies and required permits	NR	NR	NR	Drawdown feasibility study and O & M Plan Local NOI $6,000 to $8,000	NR
	Implementation	Operation can be done by dam owner, approved volunteers	NR	NR	NR	Minimal, unless alteration to outlet structure required	NR
	Post-implementation	Additional monitoring may be required specific to permit conditions	NR	NR	NR	Varies	NR
Dredging	Design/Permitting*	Dredge feasibility study and multiple required permits	NR	NR	NR	NR	NR
	Implementation	Approach varies widely	NR	NR	NR	NR	NR
	Post-implementation	Additional monitoring may be required specific to permit conditions	NR	NR	NR	NR	NR

Option	Description	Additional Information	Recommendation by Pond with Cost Estimate				
			Keyes	Burge's	Grassy	Old Mill/ Graniteville	Kennedy
Stormwater Best Management Practices (BMPs)	Design/Permitting*	Additional studies and permitting	Limited watershed BMP opportunities, primarily along eastern shoreline Cost varies but a study to refine costs would be on the order of $5,000	Trail erosion controls, as needed Cost varies but a study to refine costs would be on the order of $5,000	Trail erosion controls, as needed Cost varies but a study to refine costs would be on the order of $5,000	Road/trail erosion controls, as needed Cost varies but a study to refine costs would be on the order of $5,000	Trail erosion controls, as needed Cost varies but a study to refine costs would be on the order of $5,000
	Implementation	Approach varies widely	Typically $3,000 - $5,000 per acre treated.	Typically $3,000 - $5,000 per acre treated.	Typically $3,000 - $5,000 per acre treated.	Typically $3,000 - $5,000 per acre treated.	Typically $3,000 - $5,000 per acre treated.
	Post-implementation	Additional monitoring may be required specific to permit conditions	Annual inspection and clean-out may be required	Annual inspection and clean-out may be required	Annual inspection and clean-out may be required	Annual inspection and clean-out may be required	Annual inspection and clean-out may be required

* Significant cost savings may be achieved by combining multiple waterbodies in a given year. NR=Not currently recommended

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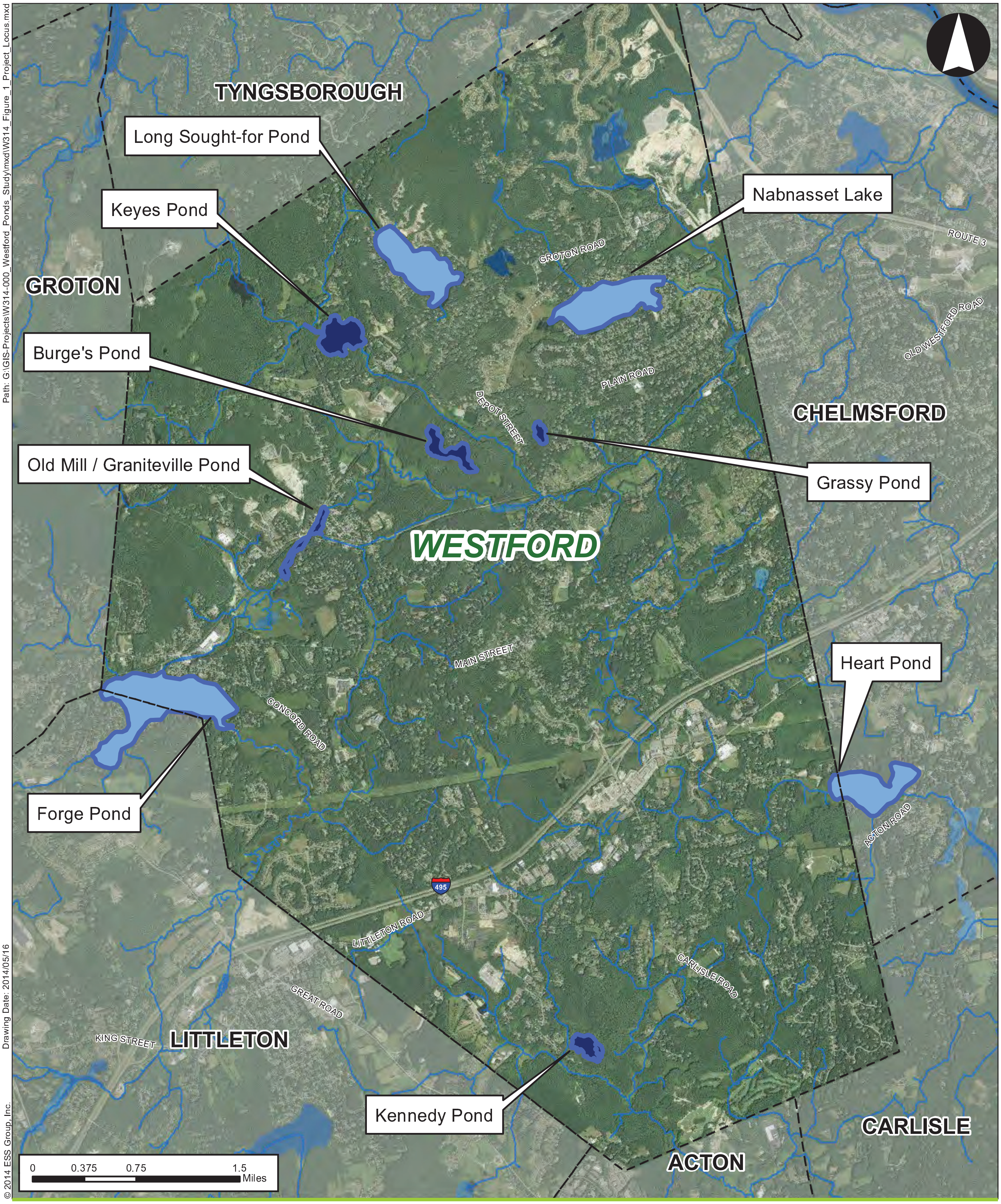
Figures



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Westford Ponds Study
Westford, Massachusetts

1 inch = 5,000 feet

Source: 1) USGS, Hydrography, 2011 2) ESRI, Online Imagery, 2011
3) EOT-OTP, Roads, 2007 4) MASSGIS, Town Boundary 2002

Legend

Ponds Included in Study
- Previously-Unstudied Ponds
- Previously-Studied Ponds
- Watercourse
- Town Boundary

Project Locus

Figure 1

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Drawing Date: 2014/05/16

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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend
- Water Quality - Surface Sampling Location
- Water Quality - Deep Hole Sampling Location
- Pond
- Watercourse

Water Quality Sampling Locations
Keyes Pond

Figure 2
Sheet 1 of 5

Drawing Date: 2014/05/16

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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

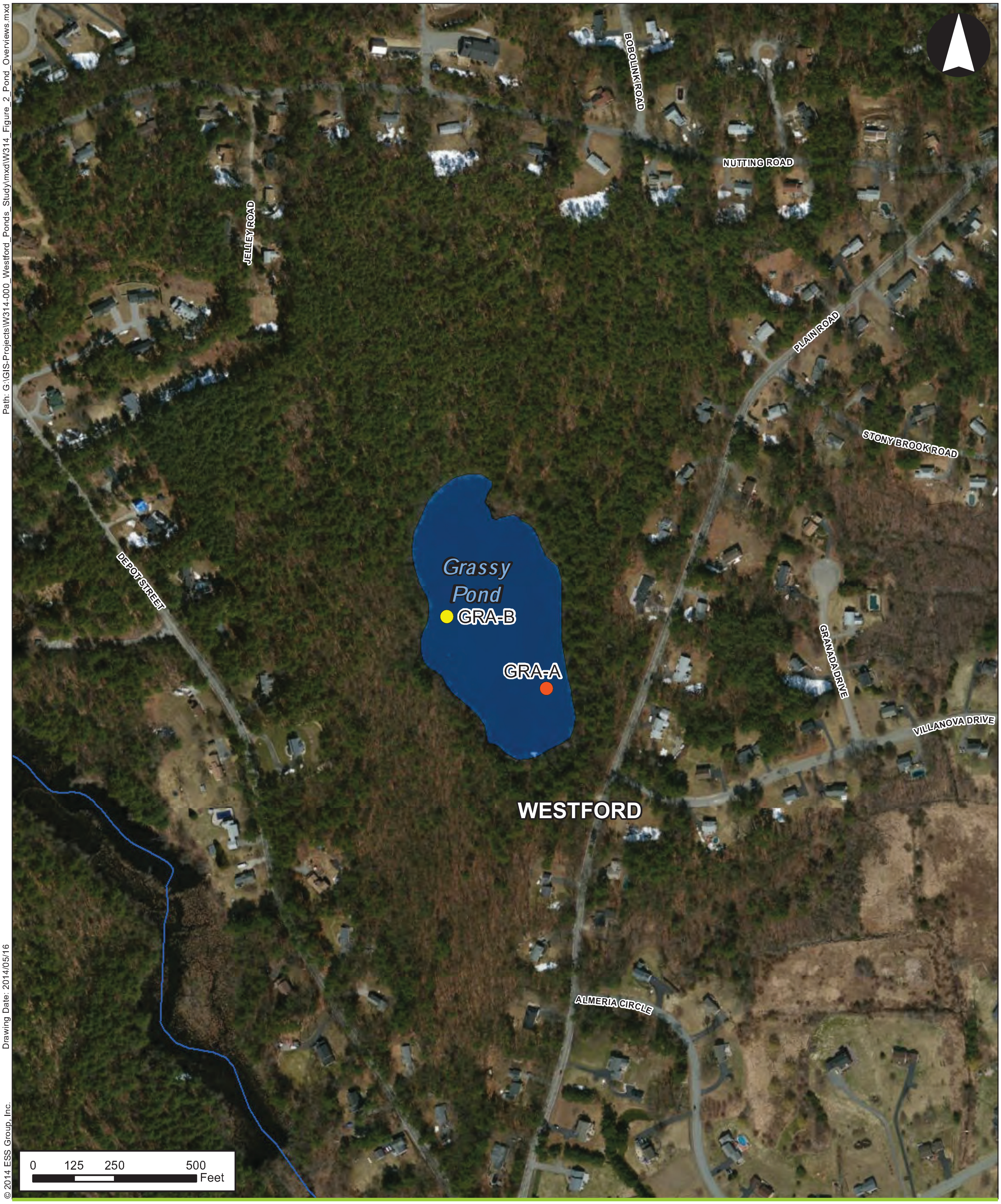
Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend
- Water Quality - Surface Sampling Location
- Water Quality - Deep Hole Sampling Location
- Pond
- Watercourse

Water Quality Sampling Locations
Burge's Pond

Figure 2
Sheet 2 of 5

Drawing Date: 2014/05/16



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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

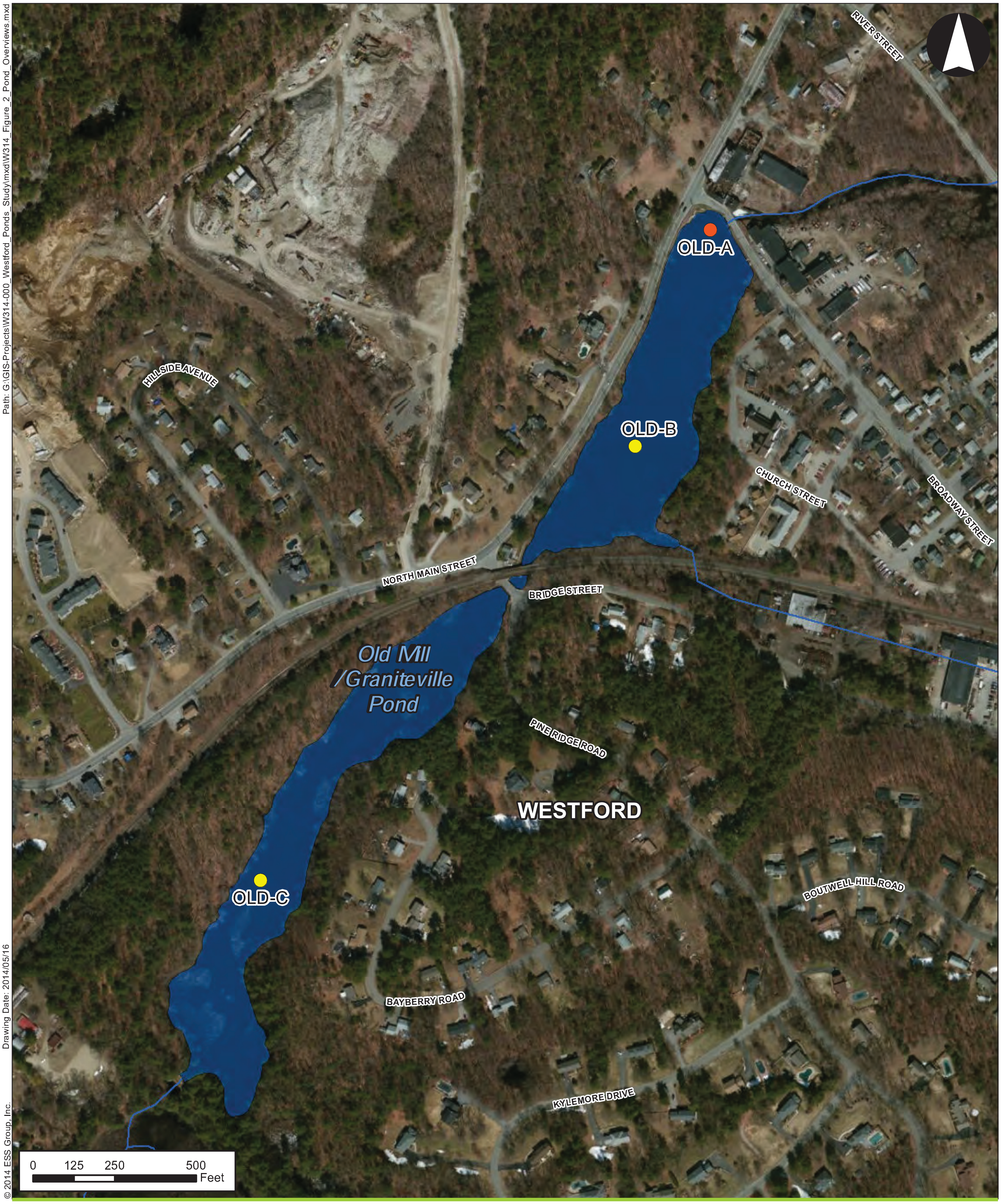
Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend

- Water Quality - Surface Sampling Location
- Water Quality - Deep Hole Sampling Location
- Pond
- Watercourse

Water Quality Sampling Locations
Grassy Pond

Figure 2
Sheet 3 of 5



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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend
- Water Quality - Surface Sampling Location
- Water Quality - Deep Hole Sampling Location
- Pond
- Watercourse

Water Quality Sampling Locations
Old Mill / Graniteville Pond

Figure 2
Sheet 4 of 5

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Drawing Date: 2014/05/16

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Westford Ponds Study
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1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend
- Water Quality - Surface Sampling Location
- Water Quality - Deep Hole Sampling Location
- Pond
- Watercourse

Water Quality Sampling Locations
Kennedy Pond

Figure 2
Sheet 5 of 5

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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

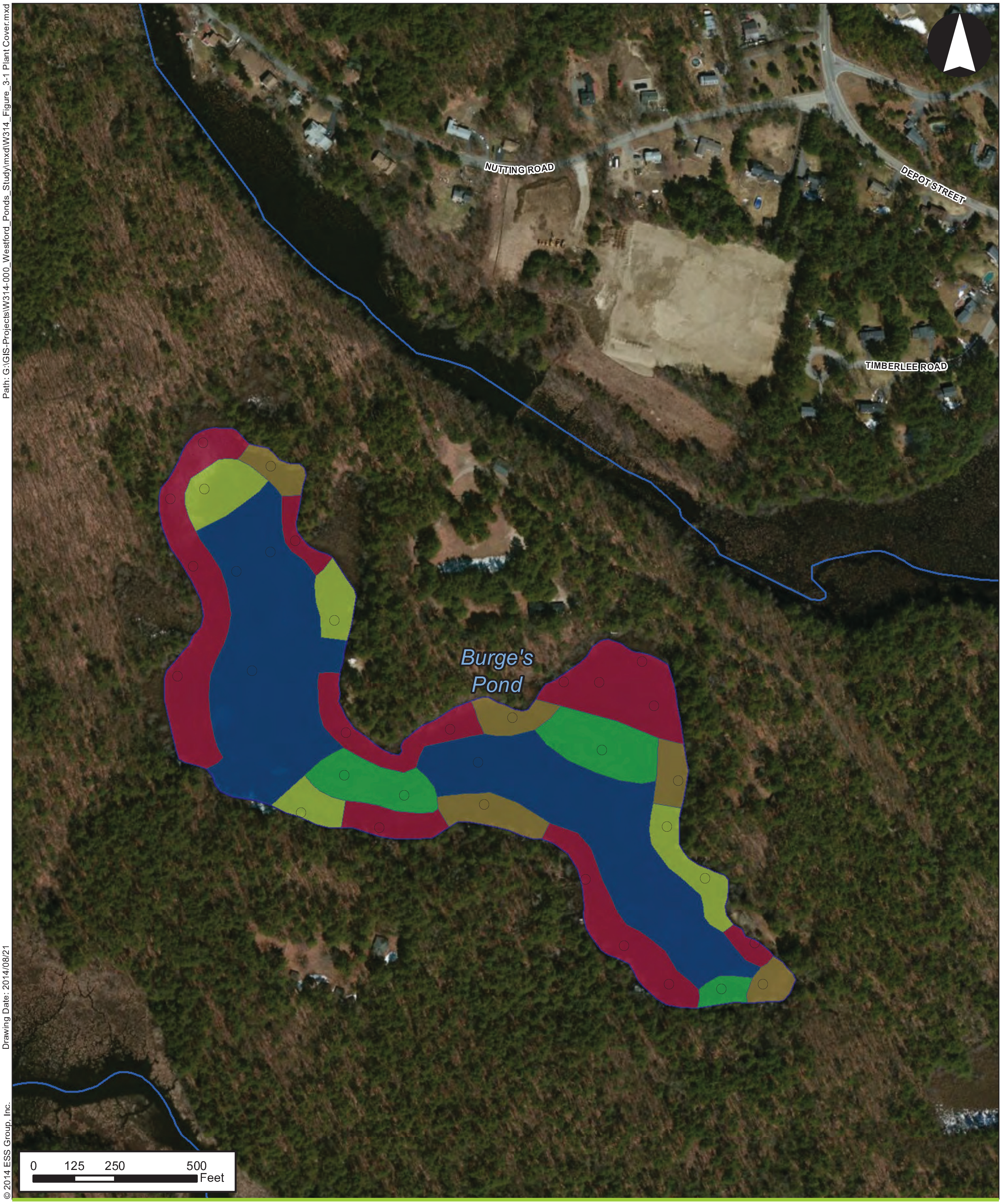
Legend

Aquatic Plant Cover
1 (1% - 25%)
2 (26% - 50%)
3 (51% - 75%)
4 (76% - 100%)

Aquatic Plant Survey Location
Pond
Watercourse

Aquatic Plant Cover
Keyes Pond

Figure 3-1
Sheet 1 of 5



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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

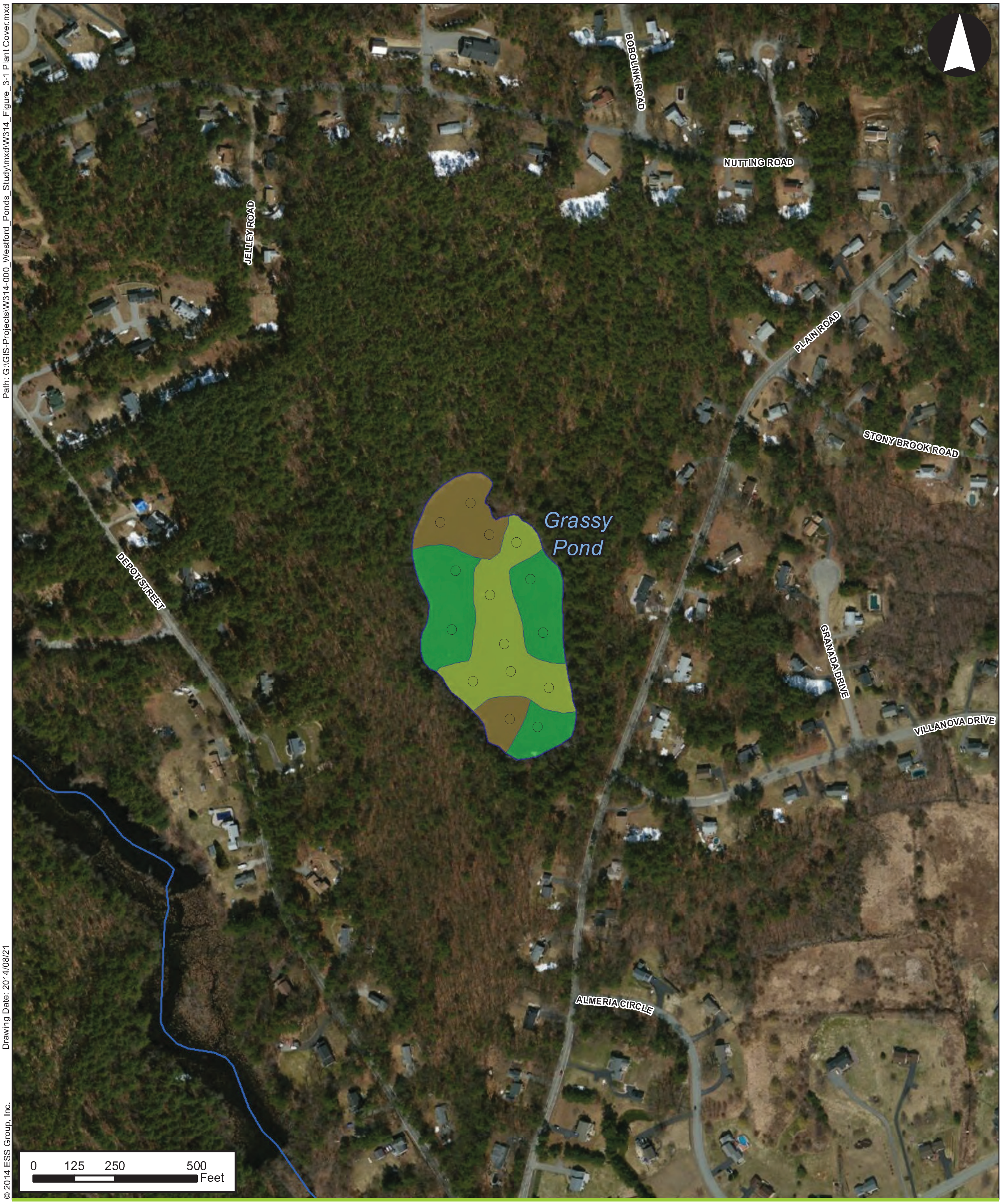
Legend

Aquatic Plant Cover
- 1 (1% - 25%)
- 2 (26% - 50%)
- 3 (51% - 75%)
- 4 (76% - 100%)

- Aquatic Plant Survey Location
- Pond
- Watercourse

Aquatic Plant Cover
Burge's Pond

Figure 3-1
Sheet 2 of 5



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1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

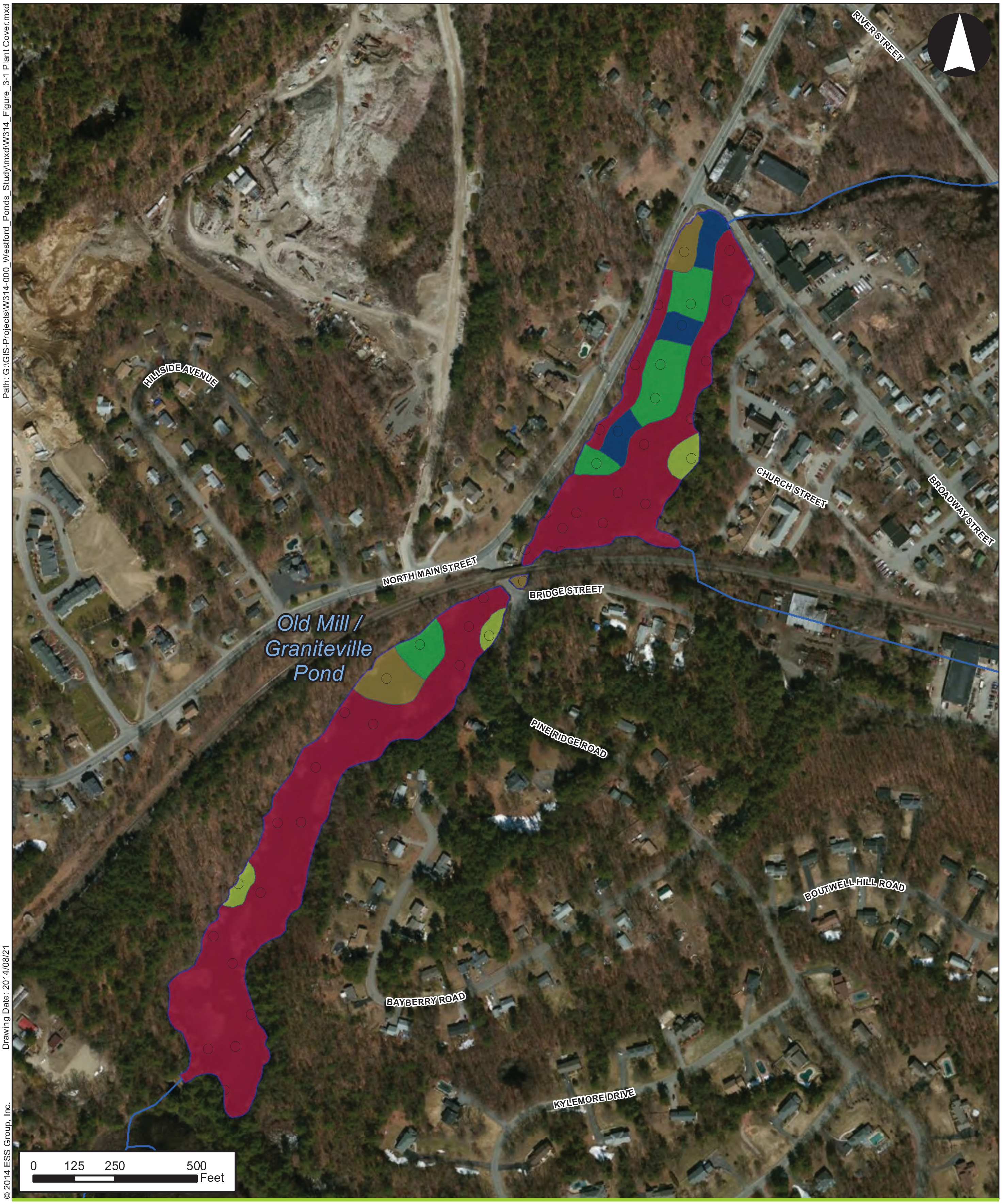
Legend

Aquatic Plant Cover
1 (1% - 25%)
2 (26% - 50%)
3 (51% - 75%)
4 (76% - 100%)

Aquatic Plant Survey Location
Pond
Watercourse

Aquatic Plant Cover
Grassy Pond

Figure 3-1
Sheet 3 of 5



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1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
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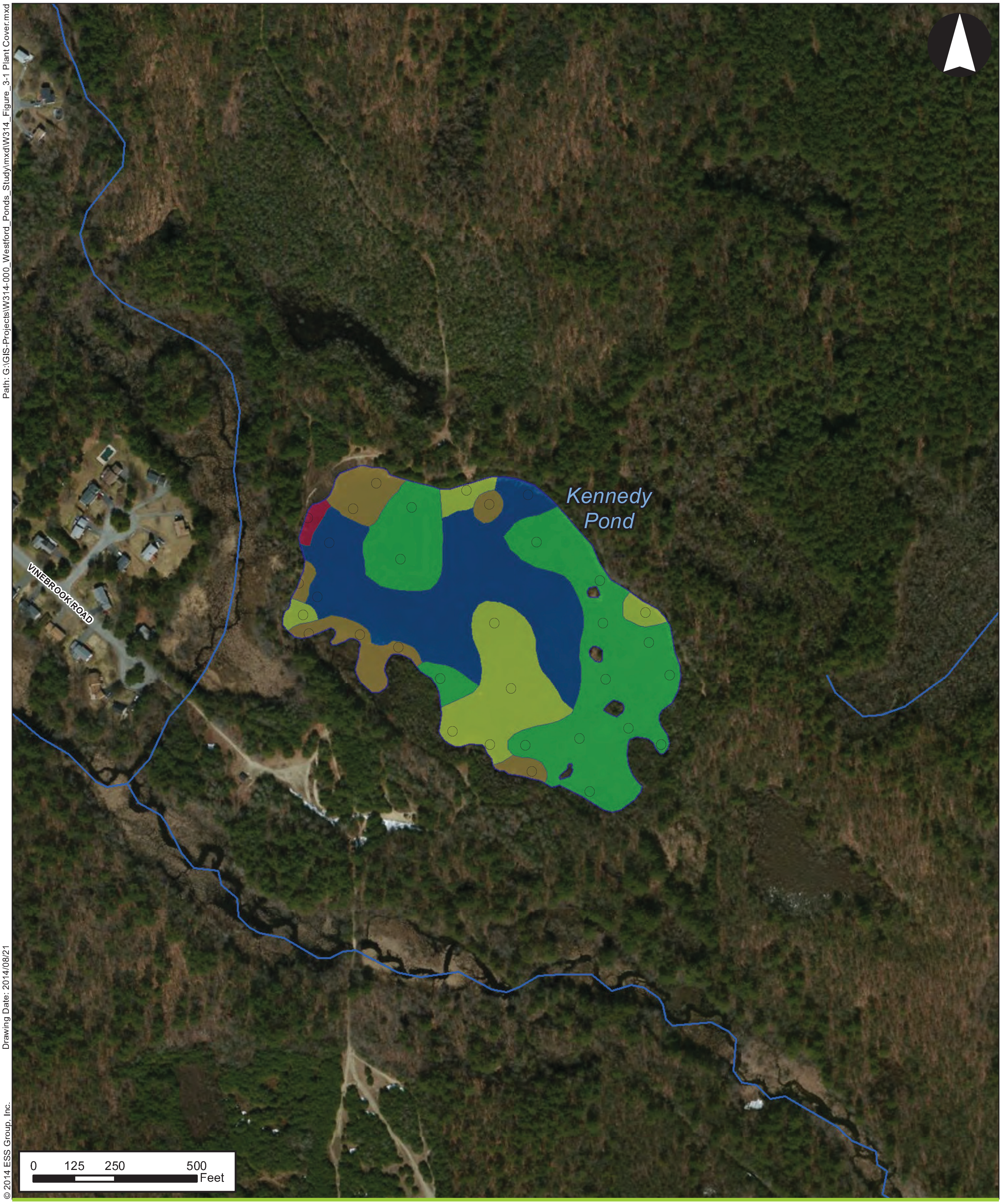
Legend

Aquatic Plant Cover
- 1 (1% - 25%)
- 2 (26% - 50%)
- 3 (51% - 75%)
- 4 (76% - 100%)
- Aquatic Plant Survey Location
- Pond
- Watercourse

Aquatic Plant Cover
Old Mill / Graniteville Pond

Figure 3-1
Sheet 4 of 5



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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend

Aquatic Plant Cover
- 1 (1% - 25%)
- 2 (26% - 50%)
- 3 (51% - 75%)
- 4 (76% - 100%)

- Aquatic Plant Survey Location
- Pond
- Watercourse

Aquatic Plant Cover
Kennedy Pond

Figure 3-1
Sheet 5 of 5

Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend

Aquatic Plant Biovolume
1 (1% - 25%)
2 (26% - 50%)
3 (51% - 75%)
4 (76% - 100%)

Aquatic Plant Survey Location
Pond
Watercourse

Aquatic Plant Biovolume
Keyes Pond

Figure 3-2
Sheet 1 of 5

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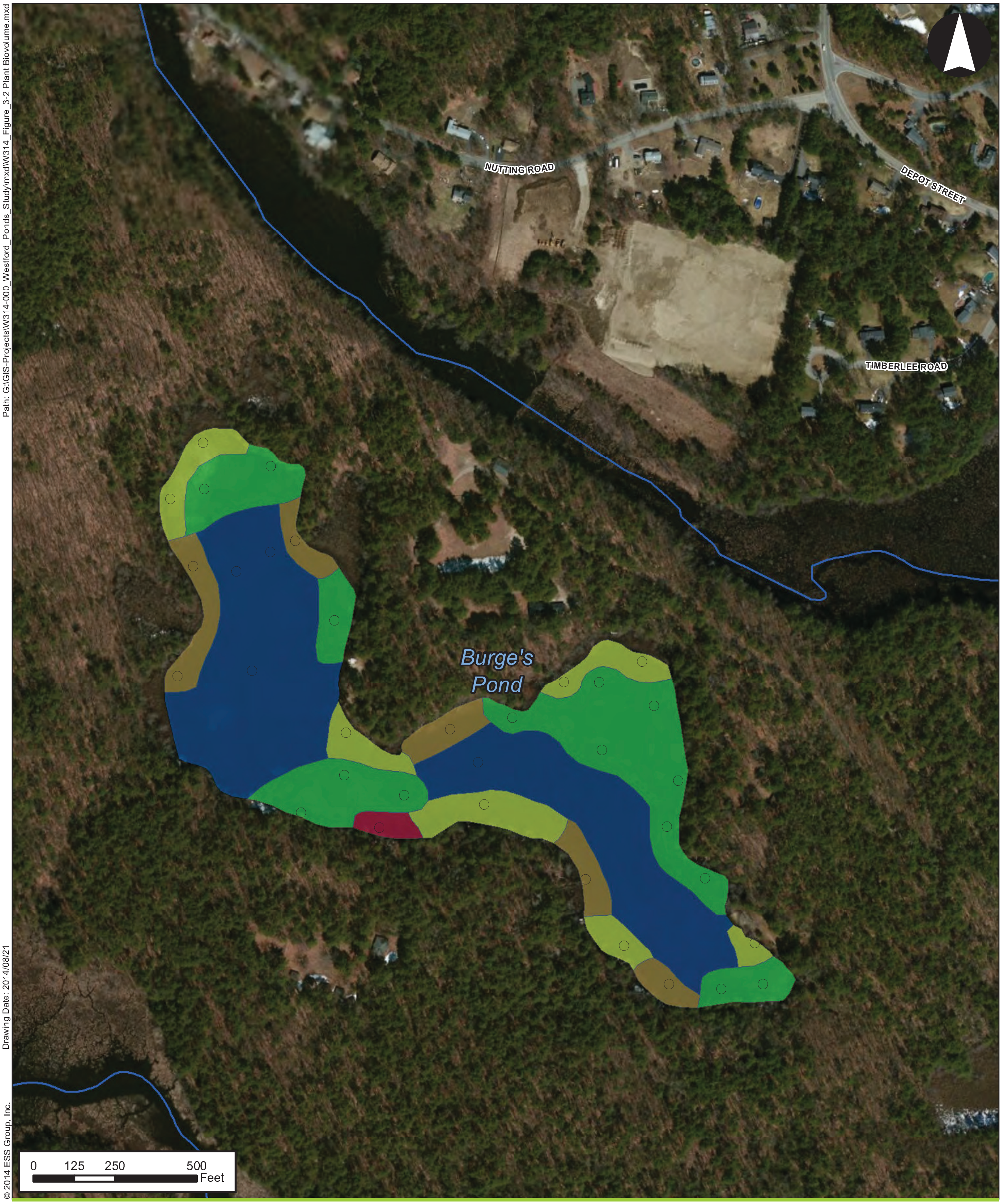

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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

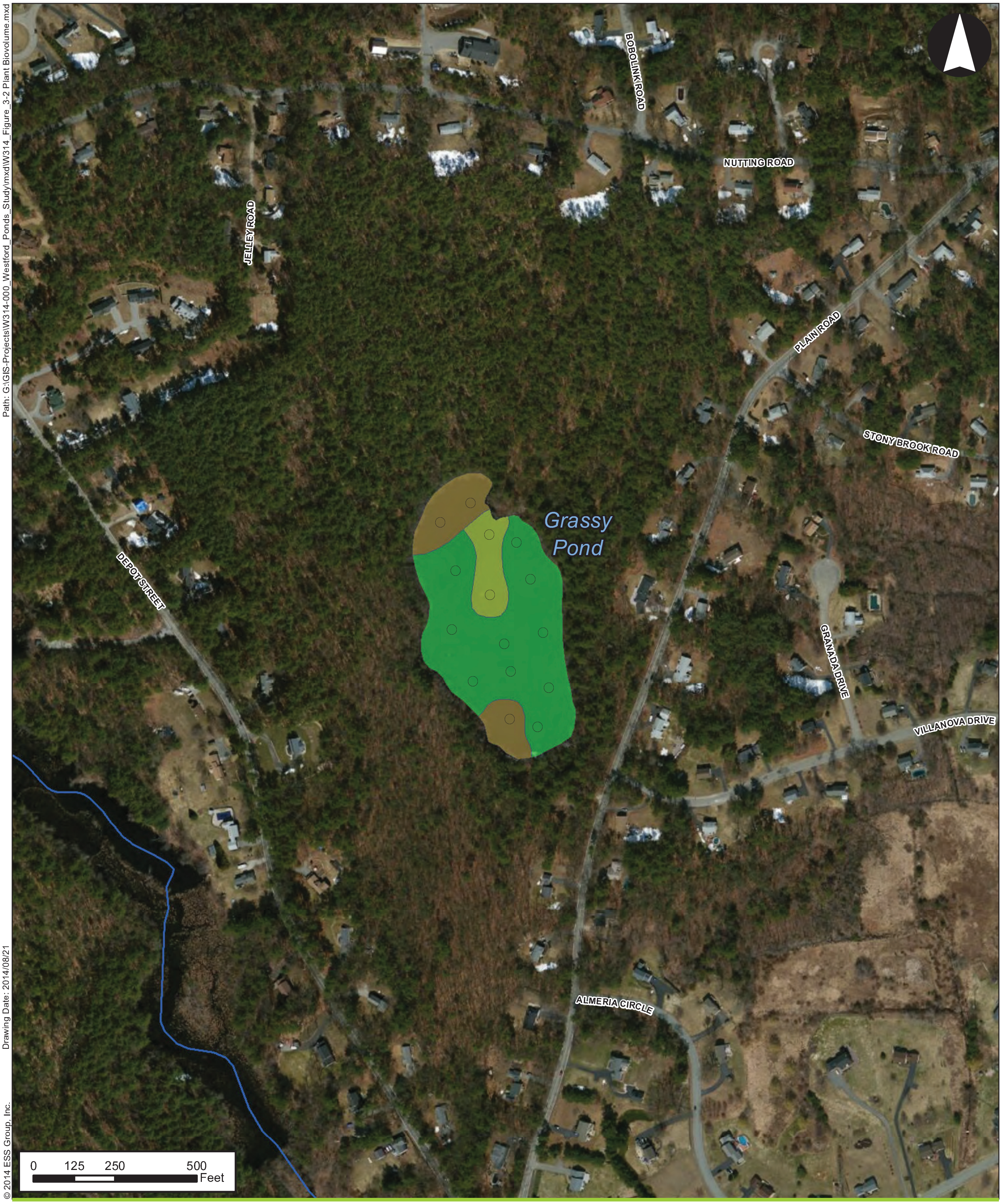
Legend

Aquatic Plant Biovolume
1 (1% - 25%)
2 (26% - 50%)
3 (51% - 75%)
4 (76% - 100%)

Aquatic Plant Survey Location
Pond
Watercourse

Aquatic Plant Biovolume
Burge's Pond

Figure 3-2
Sheet 2 of 5



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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend

Aquatic Plant Biovolume
1 (1% - 25%)
2 (26% - 50%)
3 (51% - 75%)
4 (76% - 100%)

○ Aquatic Plant Survey Location
Pond
Watercourse

Aquatic Plant Biovolume
Grassy Pond

Figure 3-2
Sheet 3 of 5

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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
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4) MASSGIS, Town Boundary, 2002

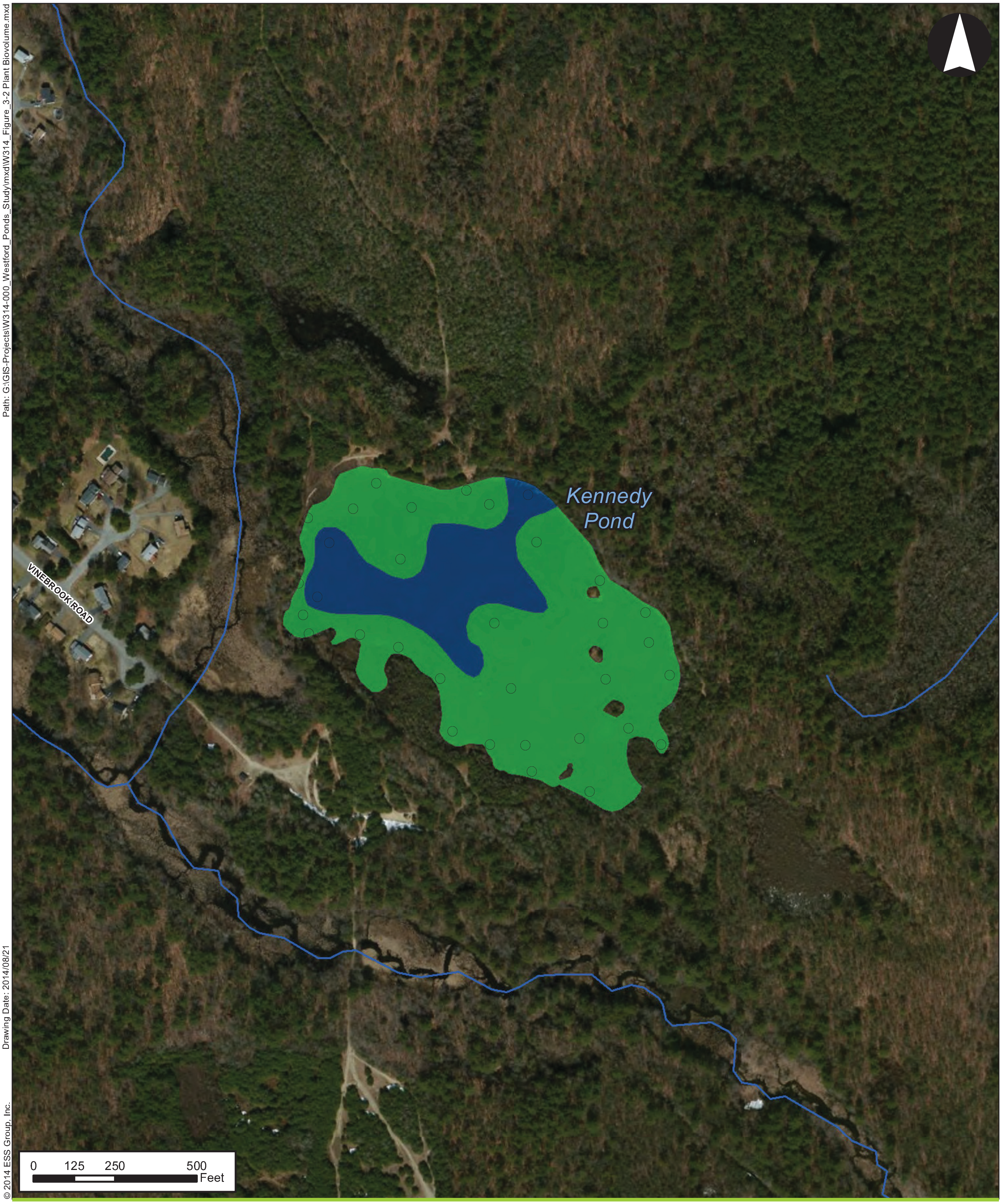
Legend

Aquatic Plant Biovolume
- 1 (1% - 25%)
- 2 (26% - 50%)
- 3 (51% - 75%)
- 4 (76% - 100%)

- Aquatic Plant Survey Location
- Pond
- Watercourse

Aquatic Plant Biovolume
Old Mill / Graniteville Pond

Figure 3-2
Sheet 4 of 5



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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

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2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

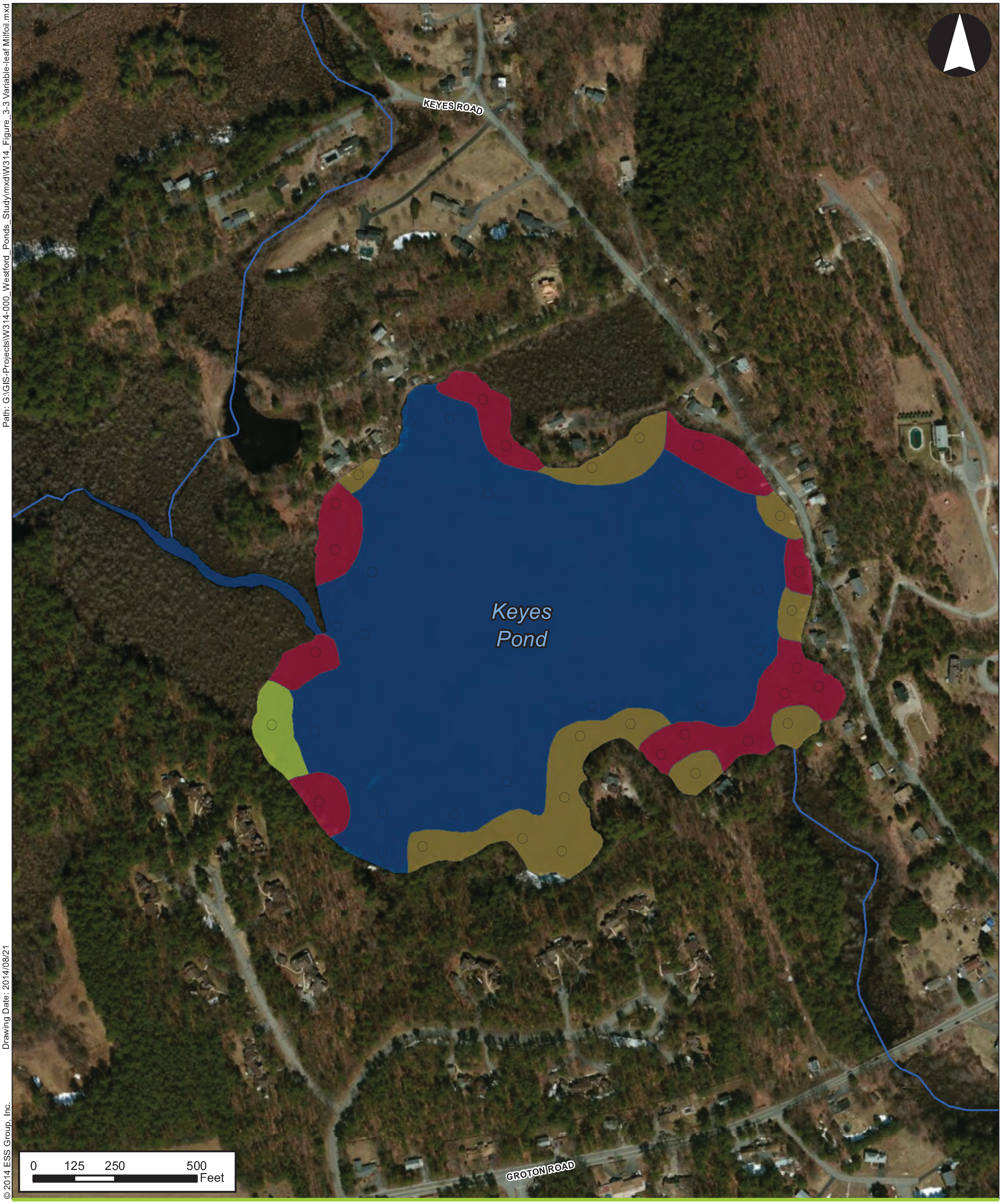
Legend

Aquatic Plant Biovolume
1 (1% - 25%)
2 (26% - 50%)
3 (51% - 75%)
4 (76% - 100%)

Aquatic Plant Survey Location
Pond
Watercourse

Aquatic Plant Biovolume
Kennedy Pond

Figure 3-2
Sheet 5 of 5



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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

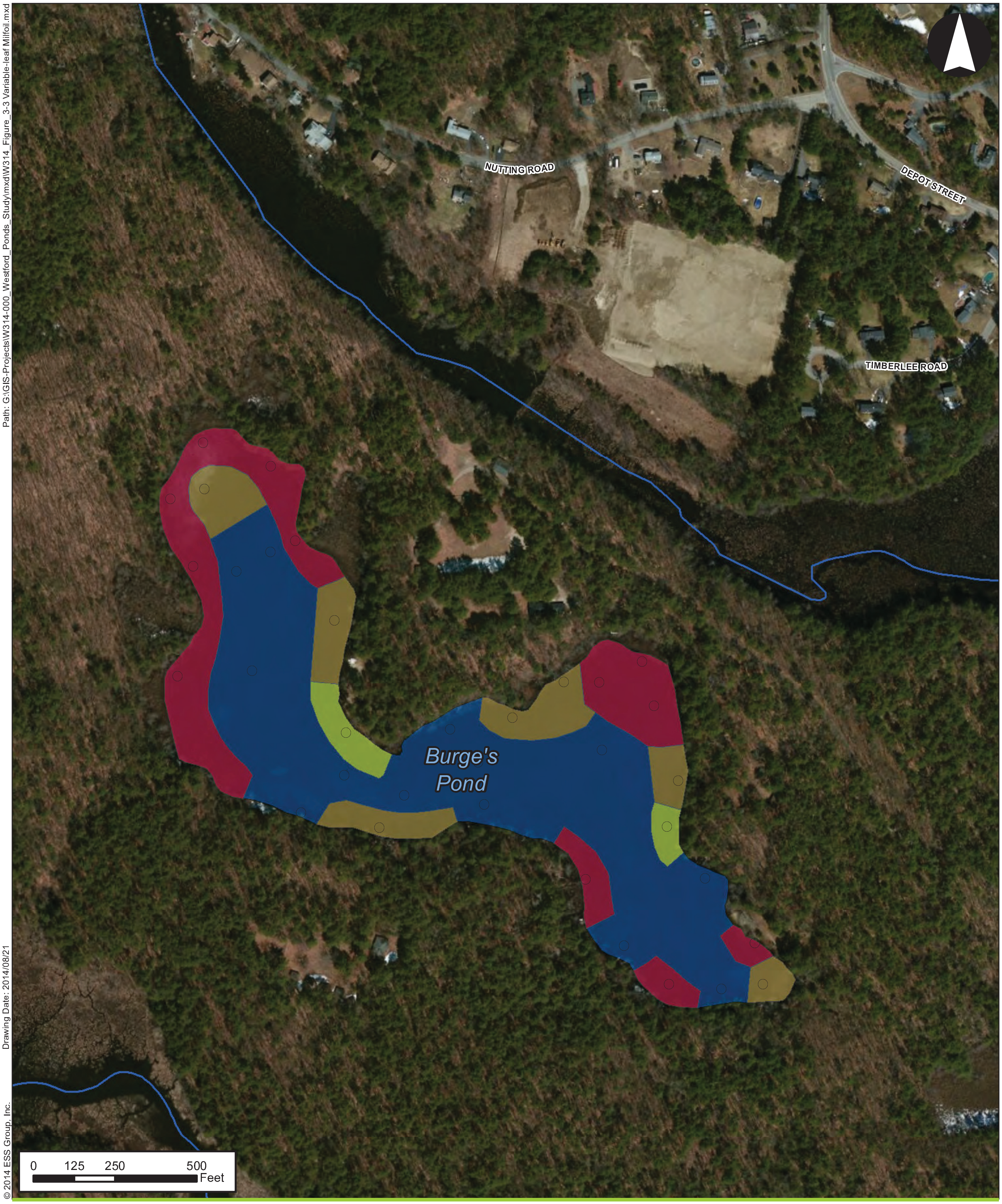
Legend

Variable-leaf Milfoil Coverage
- Sparse
- Patchy
- Dense

- Aquatic Plant Survey Location
- Pond
- Watercourse

Variable-leaf Milfoil Coverage
Keyes Pond

Figure 3-3
Sheet 1 of 5



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Westford Ponds Study

Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend

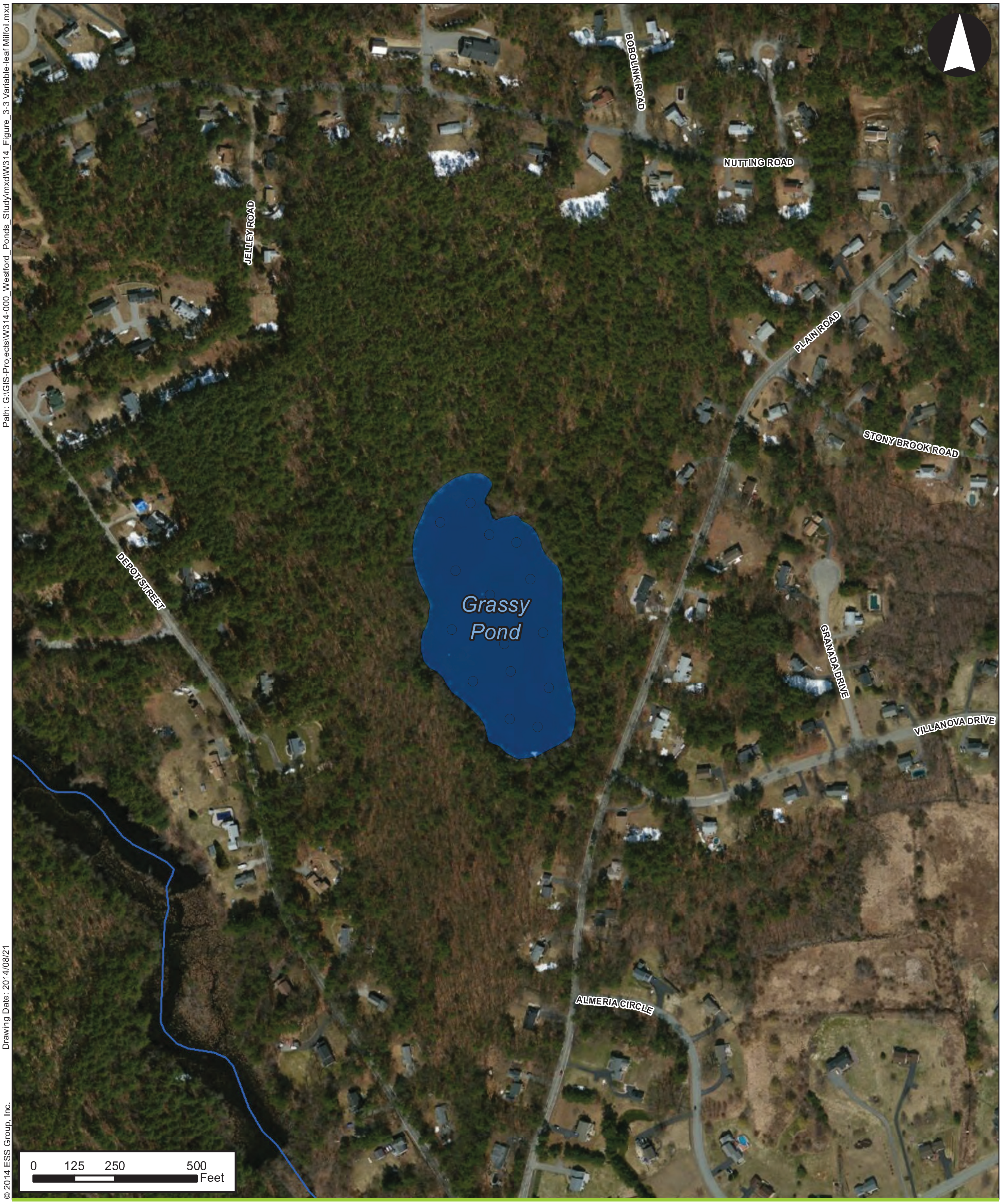
Variable-leaf Milfoil Coverage
- Sparse
- Patchy
- Dense

- Aquatic Plant Survey Location
- Pond
- Watercourse

Variable-leaf Milfoil Coverage

Burge's Pond

Figure 3-3
Sheet 2 of 5



Drawing Date: 2014/08/21

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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend

Variable-leaf Milfoil Coverage
- Sparse
- Patchy
- Dense

- Aquatic Plant Survey Location
- Pond
- Watercourse

Variable-leaf Milfoil Coverage
Grassy Pond

Figure 3-3
Sheet 3 of 5

Path: G:\GIS-Projects\W314-000_Westford_Ponds_Study\mxd\W314_Figure_3-3 Variable-leaf Milfoil.mxd

Drawing Date: 2014/08/21

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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend

Variable-leaf Milfoil Coverage
Sparse
Patchy
Dense

Aquatic Plant Survey Location
Pond
Watercourse

Variable-leaf Milfoil Coverage
Old Mill / Graniteville Pond

Figure 3-3
Sheet 4 of 5

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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend

Variable-leaf Milfoil Coverage
Sparse
Patchy
Dense

Aquatic Plant Survey Location
Pond
Watercourse

Variable-leaf Milfoil Coverage
Kennedy Pond

Figure 3-3
Sheet 5 of 5

Path: G:\GIS-Projects\W314-000_Westford_Ponds_Study\mxd\W314_Figure_3-4 Fanwort.mxd
Drawing Date: 2014/08/21

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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend

Fanwort Coverage
- Sparse
- Patchy
- Dense

- Aquatic Plant Survey Location
- Pond
- Watercourse

Fanwort Coverage
Keyes Pond

Figure 3-4
Sheet 1 of 5

Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend

Fanwort Coverage
- Sparse
- Patchy
- Dense

- Aquatic Plant Survey Location
- Pond
- Watercourse

Fanwort Coverage
Burge's Pond

Figure 3-4
Sheet 2 of 5

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Path: G:\GIS-Projects\W314-000_Westford_Ponds_Study\mxd\W314_Figure_3-4 Fanwort.mxd
Drawing Date: 2014/08/21

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Drawing Date: 2014/08/21

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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend

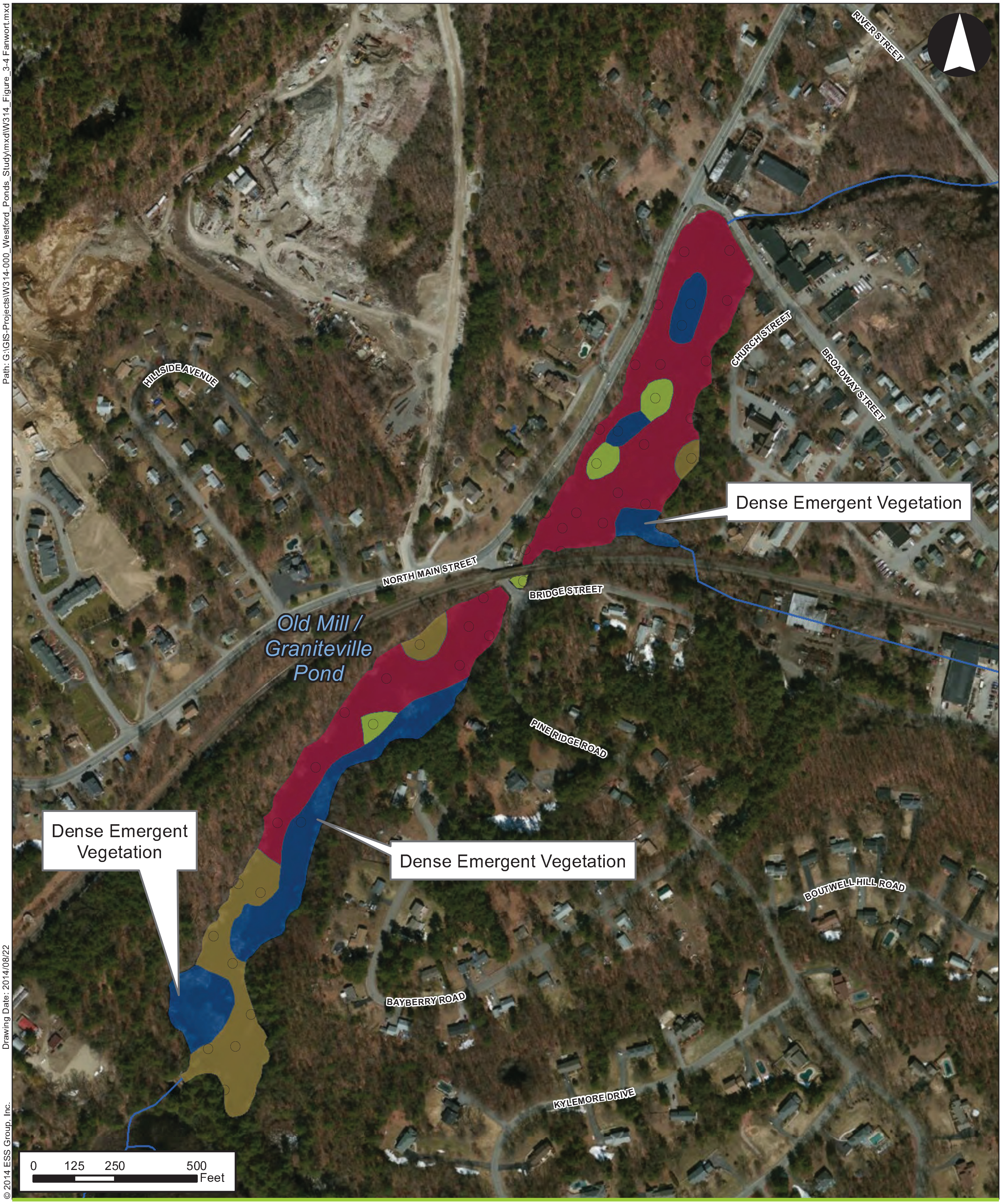
Fanwort Coverage
- Sparse
- Patchy
- Dense

- Aquatic Plant Survey Location
- Pond
- Watercourse

Fanwort Coverage
Grassy Pond

Figure 3-4
Sheet 3 of 5

Path: G:\GIS-Projects\W314-000_Westford_Ponds_Study\mxd\W314_Figure_3-4 Fanwort.mxd



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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend

Fanwort Coverage
- Sparse
- Patchy
- Dense

- Aquatic Plant Survey Location
- Pond
- Watercourse

Fanwort Coverage
Old Mill / Graniteville Pond

Figure 3-4
Sheet 4 of 5

Path: G:\GIS-Projects\W314-000_Westford_Ponds_Study\mxd\W314_Figure_3-4 Fanwort.mxd
Drawing Date: 2014/08/21

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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend

Fanwort Coverage
- Sparse
- Patchy
- Dense
- Aquatic Plant Survey Location
- Pond
- Watercourse

Fanwort Coverage
Kennedy Pond

Figure 3-4
Sheet 5 of 5

Drawing Date: 2014/08/21

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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend

Curly-leaf Pondweed Coverage
- Sparse
- Patchy
- Dense
- Aquatic Plant Survey Location
- Pond
- Watercourse

Curly-leaf Pondweed Coverage
Keyes Pond

Figure 3-5
Sheet 1 of 5

Drawing Date: 2014/08/21

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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend

Curly-leaf Pondweed Coverage
- Sparse
- Patchy
- Dense

- Aquatic Plant Survey Location
- Pond
- Watercourse

Curly-leaf Pondweed Coverage
Burge's Pond

Figure 3-5
Sheet 2 of 5

Path: G:\GIS-Projects\W314-000_Westford_Ponds_Study\mxd\W314_Figure_3-5 Curly-leaf Pondweed.mxd

Drawing Date: 2014/08/21

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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

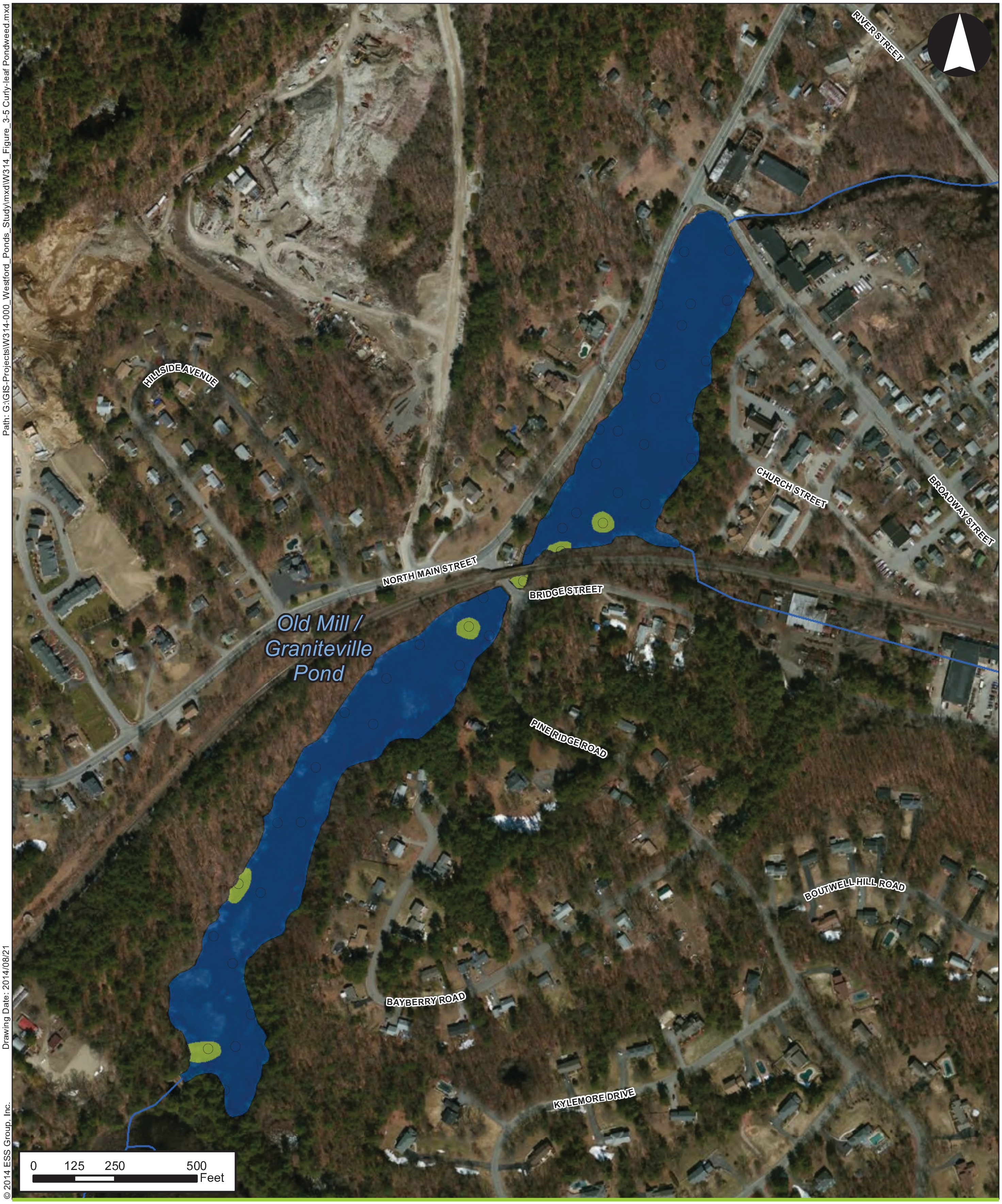
Legend

Curly-leaf Pondweed Coverage
- Sparse
- Patchy
- Dense

- Aquatic Plant Survey Location
- Pond
- Watercourse

Curly-leaf Pondweed Coverage
Grassy Pond

Figure 3-5
Sheet 3 of 5



Drawing Date: 2014/08/21

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Westford Ponds Study

Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend

Curly-leaf Pondweed Coverage

- Sparse
- Patchy
- Dense
- Aquatic Plant Survey Location
- Pond
- Watercourse

Curly-leaf Pondweed Coverage

Old Mill / Graniteville Pond

Figure 3-5
Sheet 4 of 5

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Westford Ponds Study
Westford, Massachusetts

1 inch = 400 feet

Source: 1) USGS, Hydrography, 2011
2) ESRI, Online Imagery, 2011
3) EOT, Roads, 2009
4) MASSGIS, Town Boundary, 2002

Legend

Curly-leaf Pondweed Coverage
- Sparse
- Patchy
- Dense

- Aquatic Plant Survey Location
- Pond
- Watercourse

Curly-leaf Pondweed Coverage
Kennedy Pond

Figure 3-5
Sheet 5 of 5