MASSACHUSETTS
watershed·based plans

WATERSHED-BASED PLAN

Foster's Pond

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Prepared For:

MassDEP
Commonwealth of Massachusetts
Department of Environmental Protection

Contents

Watershed-Based Plan Introduction

What is a Watershed-Based Plan?

Purpose & Need

The purpose of a Massachusetts Watershed-Based Plan (WBP) is to organize information about Massachusetts's watersheds, and present it in a format that will enhance the development and implementation of projects that will restore water quality and beneficial uses in the Commonwealth. The Massachusetts WBP follows USEPA's recommended format for "nine-element" watershed plans, as described below.

All states are required to develop WBPs, but not all states have taken the same approach. Most states develop watershed-based plans only for selected watersheds. MassDEP's approach has been to develop a tool to support statewide development of WBPs, so **that good projects in all areas of the state may be eligible for federal watershed implementation grant funds** under Section 319 of the Clean Water Act.

Background

USEPA guidelines promote the use of Section 319 funding for developing and implementing WBPs. WBPs are required for all projects implemented with Section 319 funds, and are recommended for all watershed projects, whether they are designed to protect unimpaired waters, restore impaired waters, or both.

The USEPA Guidelines list the following nine elements required to be included in WBPs:

a. An **identification of the causes and sources** or groups of similar sources that will need to be controlled to achieve the load reductions estimated in this watershed-based plan (and to achieve any other watershed goals identified in the watershed-based plan), as discussed in item (b) immediately below.

b. An **estimate of the load reductions** expected for the management measures described under paragraph (c) below (recognizing the natural variability and the difficulty in precisely predicting the performance of management measures over time).

c. A **description of the NPS management measures** needed to achieve the load reductions estimated under paragraph (b) above (as well as to achieve other watershed goals identified in this watershed-based plan), and an identification (using a map or a description) of the critical areas in which those measures will be needed to implement this plan.

d. An **estimate of the amounts of technical and financial assistance needed**, associated costs, and/or the sources and authorities that will be relied upon, to implement this plan. As sources of funding, States should consider the use of their Section 319 programs, State Revolving Funds, USDA's Environmental Quality Incentives Program and Conservation Reserve Program, and other relevant Federal, State, local and private funds that may be available to assist in implementing this plan.

e. An **information/education component** that will be used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the NPS management measures that will be implemented.

f. A **schedule for implementing the NPS management measures** identified in this plan that is reasonably expeditious.

g. A description of **interim, measurable milestones** for determining whether NPS management measures or other control actions are being implemented.

h. A set of **criteria to determine if loading reductions are being achieved** over time and substantial progress is being made towards attaining water quality standards and, if not, the criteria for determining whether this watershed-based plan needs to be revised or, if a NPS Total Maximum Daily Load (TMDL) has been established, whether the TMDL needs to be revised.

i. A **monitoring component** to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established under item (h) immediately above.

Element A: Identify Causes of Impairment & Pollution Sources

Element A: Identify the causes and sources or groups of similar sources that need to be controlled to achieve the necessary pollutant load reductions estimated in the watershed based plan (WBP).

1. General Watershed Information

The Foster's Pond ("Pond")[1] watershed is located within the towns of Andover and Wilmington, MA (see Figure A-1). The primary surface water inflow to the pond is from Frye's Brook in the northwest corner of the Pond. Additional surface water inflows are from intermittent tributaries and overland flow from nearshore areas (Proximal areas). The drainage boundaries of these areas are delineated on Figure A-1 as "Frye's Brook Watershed" and "Proximal Watershed", respectively. The primary outflow from the Pond is from the dam at the Pond's northwest corner. Water flows via an unnamed tributary (MA83-16) to the Shawsheen River.

Table A-1: General Watershed Information

Watershed Name (Assessment Unit ID):	Foster's Pond (MA83005)
Major Basin:	SHAWSHEEN
Watershed Area:	956.8 (ac)
Water Body Size:	109 (ac)

[1] For consistency, the preferred spelling of "Foster's Pond" (utilizing an apostrophe) is used throughout this document. Where quoted sources have omitted the apostrophe, the preferred spelling has been substituted.

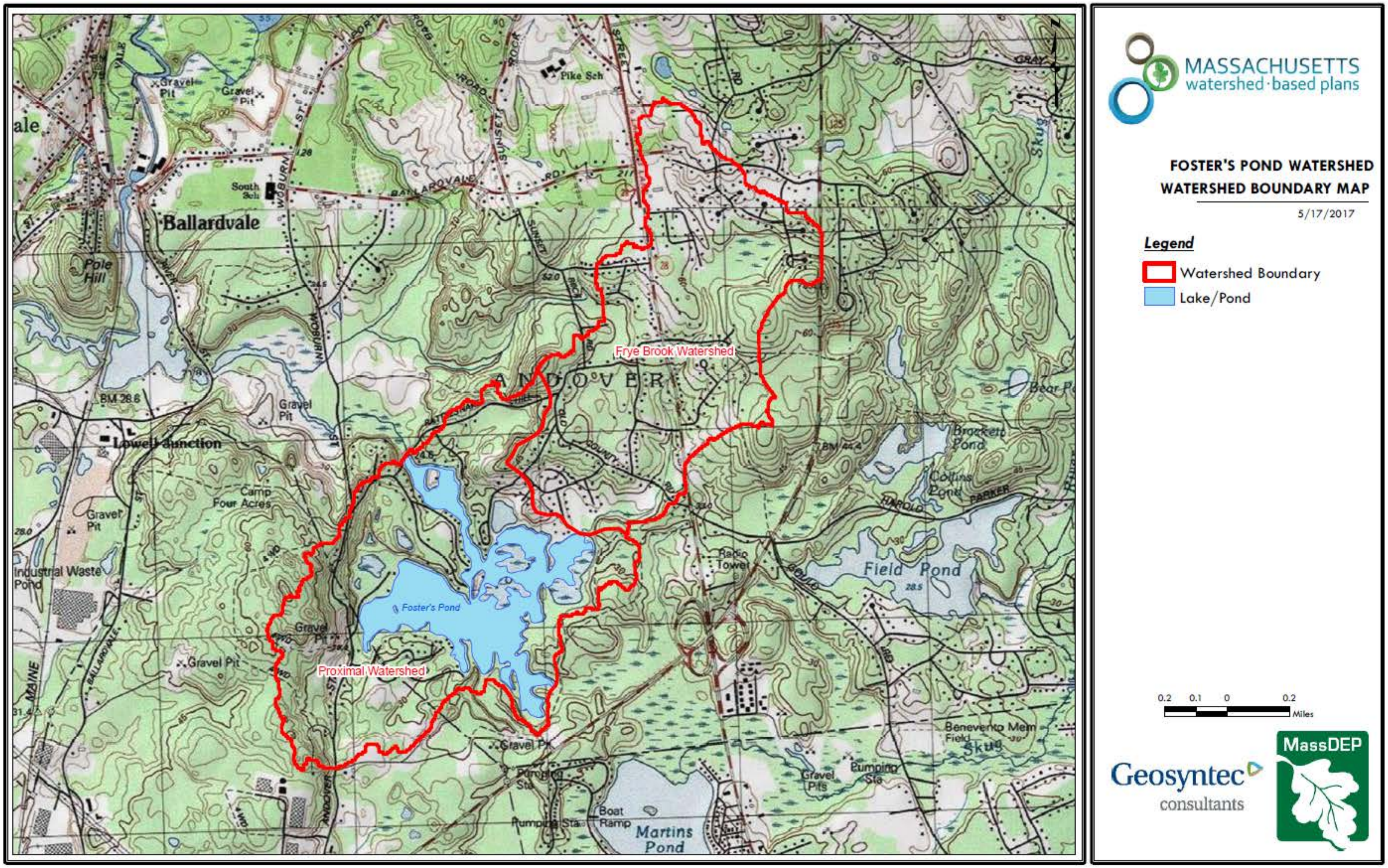


Figure A-1: Watershed Boundary Map (MassGIS, 1999; MassGIS, 2001; USGS, 2016)

2. MassDEP Water Quality Assessment Report and TMDL Review

The following reports with information related to Foster's Pond were reviewed for this study:

- Northeast Regional Mercury Total Maximum Daily Load (TMDL)
- Shawsheen River Watershed 2000 Water Quality Assessment Report

Sections relevant to Foster's Pond summarized below.

Shawsheen River Watershed 2000 Water Quality Assessment Report (MA83005 - Foster's Pond)
LAKE USE ASSESSMENTS Lake assessments are based on information gathered during DWM surveys (recent and historic) as well as pertinent information from other reliable sources (e.g., abutters, herbicide applicators, diagnostic/feasibility studies, MDPH, etc.). The 1995 DWM synoptic surveys focused on visual observations of water quality and quantity (e.g., water level, sedimentation, etc.), the presence of native and non-native aquatic plants (both distribution and aerial cover) and presence/severity of algal blooms (Appendix D, Table D4). During 2000, more intensive in-lake sampling was conducted by DWM in two lakes in the Shawsheen River Watershed as part of the TMDL program. This sampling included in-lake measurements of DO, pH, temperature, Secchi disk transparency, nutrients, and chlorophyll a, and detailed macrophyte mapping (Appendix B, Tables B1, B2, and B3). While these surveys provided additional information to assess the status of the designated uses fecal coliform bacteria data were unavailable and, therefore, the Primary Contact Recreational Use was usually not assessed. In the case of the Fish Consumption Use, fish consumption advisory information was obtained from the MDPH (MDPH 2002a). Although the Drinking Water Use was not assessed in this water quality assessment report, the Class A waters were identified. Information on drinking water source protection and finish water quality is available at http://www.state.ma.us/dep/brp/dws/dwshome.htm and from the Shawsheen River Watershed's public water suppliers. The use assessments and supporting information were entered into the EPA Waterbody System database. Data on the presence of non-native plants were entered into the MADEP DWM informal non-native plant tracking database. **AQUATIC LIFE** Non-native aquatic macrophytes were observed in 4 of the 15 lakes surveyed by DWM in 1995 (Appendix D, Table D4). The two non-native aquatic species observed in the Shawsheen River Watershed lakes were Potamogeton crispus (curly leaf pondweed) and Cabomba caroliniana (fanwort). These species have high potential for spreading and are likely to have established themselves in downstream lake and river segments in the Shawsheen River Watershed, which may not have been surveyed. Figure 10 indicates where these non-native aquatic species were observed during the DWM 1995 surveys and the likely, or potential, avenues of downstream spreading. [*See figure on page 78 of Water Quality Assessment Report*] It should also be noted that at least one non-native wetland species, either Lythrum Salicaria (purple loosestrife) or Phragmites australis (common reed grass), were observed at all but one of the 15 lakes surveyed by DWM in 1995 and/or 2000 (Appendix D, Table D4). These two non-native wetland species were co-located at Richardson Pond North (Billerica/Tewksbury) and Round Pond (Tewksbury). Although the presence of these species is not generally a cause of impairment to lakes, their invasive growth habit can result in the impairment of wetland habitat associated with lakes. Oxygen depletion occurred below 1.5 m during August and 0.5 m in September 2000 at Foster's Pond (Appendix B, Table B1). Because oxygen depletion occurs at such a shallow depth, the entire pond is assessed as impaired for the Aquatic Life Use as a result of organic enrichment/low DO, as well as the exotic species. The Aquatic Life Use was assessed as impaired in three lakes (Gravel Pit, Lowell Junction, and Pomps ponds) with confirmed non-native macrophyte(s). Two additional lakes, Foster's and Long ponds, were impaired for both organic enrichment/low DO and non-native macrophytes. The remaining 10 lakes in the Shawsheen River Watershed were not assessed for the Aquatic Life Use because of the cursorial nature of the synoptic surveys and/or the lack of DO data observations. **FISH CONSUMPTION** In June 2002, MDPH issued new consumer advisories on fish consumption and mercury contamination. The MDPH "…is advising pregnant women, women of childbearing age who may become pregnant, nursing mothers and children under 12 years of age to refrain from eating the following marine fish; shark, swordfish, king mackerel, tuna steak and tilefish. In addition, MDPH is

expanding its previously issued statewide fish consumption advisory which cautioned pregnant women to avoid eating fish from all freshwater bodies due to concerns about mercury contamination, to now include women of childbearing age who may become pregnant, nursing mothers and children under 12 years of age (MDPH 2001)."

Additionally, MDPH "…is recommending that pregnant women, women of childbearing age who may become pregnant, nursing mothers and children under 12 years of age limit their consumption of fish not covered by existing advisories to no more than 12 ounces (or about 2 meals) of cooked or uncooked fish per week. This recommendation includes canned tuna, the consumption of which should be limited to 2 cans per week. Very small children, including toddlers, should eat less. Consumers may wish to choose to eat light tuna rather than white or chunk white tuna, the latter of which may have higher levels of mercury (MDPH 2001)."

MDPH's statewide advisory does not include fish stocked by the state Division of Fisheries and Wildlife or farm-raised fish sold commercially. The advisory encompasses all freshwaters in Massachusetts and, therefore, the Fish Consumption Use for lakes in the Shawsheen River Watershed cannot be assessed as support.

In August and September 2000 fish toxics monitoring (metals, PCB, and organochlorine pesticide in edible fillets) was conducted by DWM in Foster's Pond, Andover and Round Pond, Tewksbury, respectively, at the request of the Shawsheen Watershed Team for human consumption considerations. PCB was not detected in any of the samples analyzed (Appendix C, Table C1). Mercury concentrations were above the MDPH action level of 0.5 PPM in fish from Foster's Pond. Because of elevated mercury concentrations MDPH issued a fish consumption advisory in May 2001 due to mercury contamination for Foster's Pond in Andover/Wilmington (MDPH 2002a). The advisory recommends the following.

Foster's Pond (Andover/Wilmington):
1. "Children younger than 12 years, pregnant women, and nursing mothers should not eat any fish from this water body."
2. "The general public should limit consumption of all fish from this water body to two meals per month."

PRIMARY AND SECONDARY CONTACT RECREATION AND AESTHETICS

Two ponds, Long Pond in Tewksbury, and Foster's Pond, Andover, were assessed as impaired for the Recreational and Aesthetics uses. In Long Pond all of the Secchi disk depth measurements violated the bathing beach guidance of four feet (Appendix B, Table B2). Because of the presence of algae and duckweed blooms the Primary and Secondary Contact Recreational and Aesthetic uses are assessed as impaired. Only 13% of the lake biovolume, however, has dense/very dense vegetation.

Approximately 77% of Foster's Pond biovolume (the 3-dimensional space available for biological growth) has dense/very dense vegetation dominated by Cabomba caroliniana.[2] Because of this high percentage of biovolume of a non-native aquatic plant the Primary and Secondary Contact Recreational and Aesthetic uses are assessed as impaired. None of the Secchi disk depth measurements in Foster's Pond violated the bathing beach guidance of four feet (Appendix B, Table B2).

TROPHIC STATUS EVALUATION

Lakes are dynamic ecosystems that undergo a process of succession from one trophic state to another. Under natural conditions most lakes move from a nutrient poor (oligotrophic) condition, through an intermediate (mesotrophic) stage of nutrient availability and biological productivity, to a nutrient-rich or highly productive (eutrophic) state. For the purposes of this report trophic status was estimated primarily using visual observations of macrophyte cover and phytoplankton populations observed in 1995 and/or 2000 by MADEP DWM (Appendix D, Table D4). A more definitive assessment of trophic status requires more extensive collection of water quality and biological data than is currently available. As available data become more than five years old, trophic status estimates are generally listed as undetermined. This is particularly true if the lake was previously estimated to be oligo- or mesotrophic, since conditions may have moved to a more productive status in the interim.

The trophic status estimates for the lakes assessed in the Shawsheen River Watershed are presented in Table 21; Foster's Pond was assessed to be eutrophic.

[See table on page 77 of Water Quality Assessment Report]

[2] Under a lake management program initiated in 2005, the Foster's Pond Corporation has controlled fanwort through the periodic application of fluridone. In 2016, a vegetation survey conducted by Solitude Lake Management, Inc., estimated fanwort cover at 0.2%.

3. Foster's Pond-Specific Literature Review

The following relevant Pond-specific references were reviewed when preparing the Foster's Pond Watershed Based Plan:

- A 29-page report dated February 10, 2017 was prepared by Solitude Lake Management summarizing results from the 2016 Aquatic Management Program. The primary focus of the report is on vegetation management. However, page 8 of the report summarizes water quality monitoring data from sampling locations throughout the pond, including: Mill Reservoir (WQ1), Main Pond (WQ3), Dug Pond (WQ2), Outlet Cove (WQ4), and Azalea Drive (WQ5). The report contains information on bacteria (fecal coliform) and phosphorus measurements. Bacteria measurements were taken at all sampling locations and was only detected at Mill Reservoir. Additional annual reports are available on the Corporation's website summarizing efforts and results from previous years.

- Mr. Stephen Cotton of the Foster's Pond Corporation (FPC) prepared a graphic and table summarizing total phosphorus (TP) concentration measurements taken at each of the above referenced locations from 2004 through 2016, typically during the summer. Mr. Cotton also provided data from two dates in April 2017, which represent TP concentrations at WQ1, WQ3, and WQ4 both before and after hydroraking was conducted in the Pond (See Table A-2). The table additionally includes precipitation data from a local Weather Underground station and information from the U.S. Drought Monitor.

Table A-2: Foster's Pond Total Phosphorus (µg/L)

Date	Mill Reservoir (WQ1)	Dug Pond (WQ2)	Main Pond (WQ3)	Outlet Cove (WQ4)	Azalea Drive (WQ5)	Precip. (2 days)	Precip. (1 week)	Precip. (1 mo.)
8/16/2004	-	-	22	-	-	-	-	-
9/2/2008	<10	<10	30	30	-	0.0	0.0	1.8
8/27/2009	27	12	46	35	-	0.3	1.9	6.2
8/23/2012	40	14	40	60	40	0.1	0.9	5.5
8/28/2014	16	5	25	16	10	0.1	0.7	3.3
9/9/2015	17	18	33	21	-	0.1	0.6	3.8
9/1/2016	16	<10	36	12	-	0.1	0.6	4.9
4/24/2017	<10	-	<10	<10	-	0.0	0.8	6.8
4/27/2017	12	-	16	14	-	0.6	1.9	7.2
Average	17.3	9.8	28.1	24.1	25.0	0.1	0.9	4.9

Notes:

1. Values highlighted blue represent measurements that were below lab detection limit of 10 µg/L

2. To calculate averages, values below lab detection limit were assumed to be 5 µg/L, which is half of the detection limit

3. Measurements from 8/23/2012 and 9/1/2016 were during an abnormally dry and extreme drought conditions, respectively

- Results indicate that concentrations during the monitoring period of record have ranged from <10 µg/L (i.e. below detection limit) to 60 µg/L. The highest concentrations were typically observed within the Main Pond, with 6 out of 9 measurements exceeding the eutrophic pond benchmark of 25 µg/L (USEPA, 1986). Concentrations exceeding 25 µg/L were also observed in Mill Reservoir (2 of 8) and Outlet Cove (3 of 9). The average concentration of all measurements is 21 µg/L, and the average is 23.5 µg/L when excluding results from Dug Pond, which has no direct surface flow connection to Foster's Pond. These results were used to assess initial results from the trophic modeling task presented below in Section 7 of WBP Element A.

- A 65-page report dated December 6, 2016 was prepared by GEI Consultants summarizing results from an inspection of the dam. Data included in this report was used in subsequent calculations of overall volume of the pond.

- The Town of Andover provided data from the assessor's database for the project area. The data included septic system records from 1978 to present for residences located within a 200-foot buffer zone of Foster's Pond. The data included the address, owner, building type, year of septic installation, and number of bedrooms. This data was used in subsequent calculations of septic system pollutant loading to the pond (See Element A, Section 7).

4. Water Quality Impairments

Known water quality impairments, as documented in the Massachusetts Department of Environmental Protection (MassDEP) 2012 Massachusetts Integrated List of Waters, are listed below. Impaired waters may require the calculation of a Total Maximum Daily Load, which is defined and discussed in Section A.5. Impairment categories from the Integrated List are as follows:

Table A-3: 2012 MA Integrated List of Waters Categories

Integrated List Category	Description
1	Unimpaired and not threatened for all designated uses.
2	Unimpaired for some uses and not assessed for others.
3	Insufficient information to make assessments for any uses.
4	Impaired or threatened for one or more uses, but not requiring calculation of a Total Maximum Daily Load (TMDL), including: 4a: TMDL is completed 4b: Impairment controlled by alternative pollution control requirements 4c: Impairment not caused by a pollutant - TMDL not required
5	Impaired or threatened for one or more uses and requiring preparation of a TMDL.

Table A-4: Water Quality Impairments

Assessment Unit ID	Waterbody	Integrated List Category	Designated Use	Impairment Cause	Impairment Source
MA83005	**Foster's Pond**	**5**	Aesthetic	Non-Native Aquatic Plants	Introduction of Non-native Organisms (Accidental or Intentional)
MA83005	**Foster's Pond**	**5**	Fish Consumption	Mercury in Fish Tissue	Atmospheric Deposition - Toxics
MA83005	**Foster's Pond**	**5**	Fish, other Aquatic Life and Wildlife	Non-Native Aquatic Plants	Introduction of Non-native Organisms (Accidental or Intentional)
MA83005	**Foster's Pond**	**5**	Fish, other Aquatic Life and Wildlife	Oxygen, Dissolved	Source Unknown
MA83005	**Foster's Pond**	**5**	Primary Contact Recreation	Non-Native Aquatic Plants	Introduction of Non-native Organisms (Accidental or Intentional)
MA83005	**Foster's Pond**	**5**	Secondary Contact Recreation	Non-Native Aquatic Plants	Introduction of Non-native Organisms (Accidental or Intentional)

5. Water Quality Goals

Water quality goals may be established for a variety of purposes, including the following:

a.) For **water bodies with known impairments**, a Total Maximum Daily Load (TMDL) is established by MassDEP and the United States Environmental Protection Agency (USEPA) as the maximum amount of the target pollutant that the waterbody can receive and still safely meet water quality standards. If the waterbody has a TMDL for total phosphorus (TP) or total nitrogen (TN), or total suspended solids (TSS), that information is provided below and included as a water quality goal.

b.) For **water bodies without a TMDL for total phosphorus** (TP), a default water quality goal for TP is based on target concentrations established in the Quality Criteria for Water (USEPA, 1986) (also known as the "Gold Book"). The Gold Book states that TP should not exceed 50 ug/L in any stream at the point where it enters any lake or reservoir, nor 25 ug/L within a lake or reservoir. For the purposes of developing WBPs, MassDEP has adopted 50 ug/L as the TP target for all streams at their downstream discharge point, regardless of which type of water body the stream discharges to.

c.) Massachusetts Surface Water Quality Standards (314 CMR 4.00, 2013) prescribe the minimum water quality criteria required to sustain a waterbody's designated uses. Foster's Pond is a Class 'B' waterbody (Table A-5)[3]. Water quality criteria based on the Massachusetts Surface Water Quality Standards are presented below in Table A-6. The water quality goal for fecal coliform bacteria is based on the Massachusetts Surface Water Quality Standards.

[3] Class B waters are designated as a habitat for fish, other aquatic life, and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation.

Table A-5: Surface Water Quality Classification by Assessment Unit ID

Assessment Unit ID	Waterbody	Class
MA83005	Foster's Pond	B

d.) **Other water quality goals set by the community** (e.g., protection of high quality waters, in-lake phosphorus concentration goal to reduce recurrence of cyanobacteria blooms, etc.).

Table A-6: Water Quality Goals

Pollutant	Goal	Source
Total Phosphorus (TP)	Total phosphorus should not exceed: --50 ug/L in any stream --25 ug/L within any lake or reservoir	Quality Criteria for Water (USEPA, 1986)
Bacteria	**Class B Standards** • Public Bathing Beaches: For E. coli, geometric mean of 5 most recent samples shall not exceed 126 colonies/ 100 ml and no single sample during the bathing season shall exceed 235 colonies/100 ml. For enterococci, geometric mean of 5 most recent samples shall not exceed 33 colonies/100 ml and no single sample during bathing season shall exceed 61 colonies/100 ml; • Other Waters and Non-bathing Season at Bathing Beaches: For E. coli, geometric mean of samples from most recent 6 months shall not exceed 126 colonies/100 ml (typically based on min. 5 samples) and no single sample shall exceed 235 colonies/100 ml. For enterococci, geometric mean of samples from most recent 6 months shall not exceed 33 colonies/100 ml, and no single sample shall exceed 61 colonies/100 ml.	Massachusetts Surface Water Quality Standards (314 CMR 4.00, 2013)

Note: *There may be more than one water quality goal for bacteria due to different Massachusetts Surface Water Quality Standards Classes for different Assessment Units within the watershed.*

6. Land Use Information

Land use information is presented based on the general watershed land use as well as the amount of impervious cover.

Watershed Land Uses

Table A-7: Watershed Land Uses

Land Use	Proximal Watershed (acres)	Frye's Brook Watershed (acres)	% of Entire Watershed
Agriculture	0.0	9.5	1
Commercial	0.0	9.4	1
Forest	342.1	217.0	58.4
High Density Residential	0.0	0.0	0
Highway	0.0	0.0	0
Industrial	1.3	1.6	0.3
Low Density Residential	69.3	148.0	22.7
Medium Density Residential	19.3	52.7	7.5
Open Land	5.4	3.7	0.9
Water	76.8[4]	0.1	8
Totals	514.3	442.2	-

[4] "Water" Land use shown in Table A-7 differs from waterbody size reported in Table A-1 as a result of different GIS sources (MassGIS 2005 Landuse Layer vs. MassGIS Hydrography Layer, respectively).

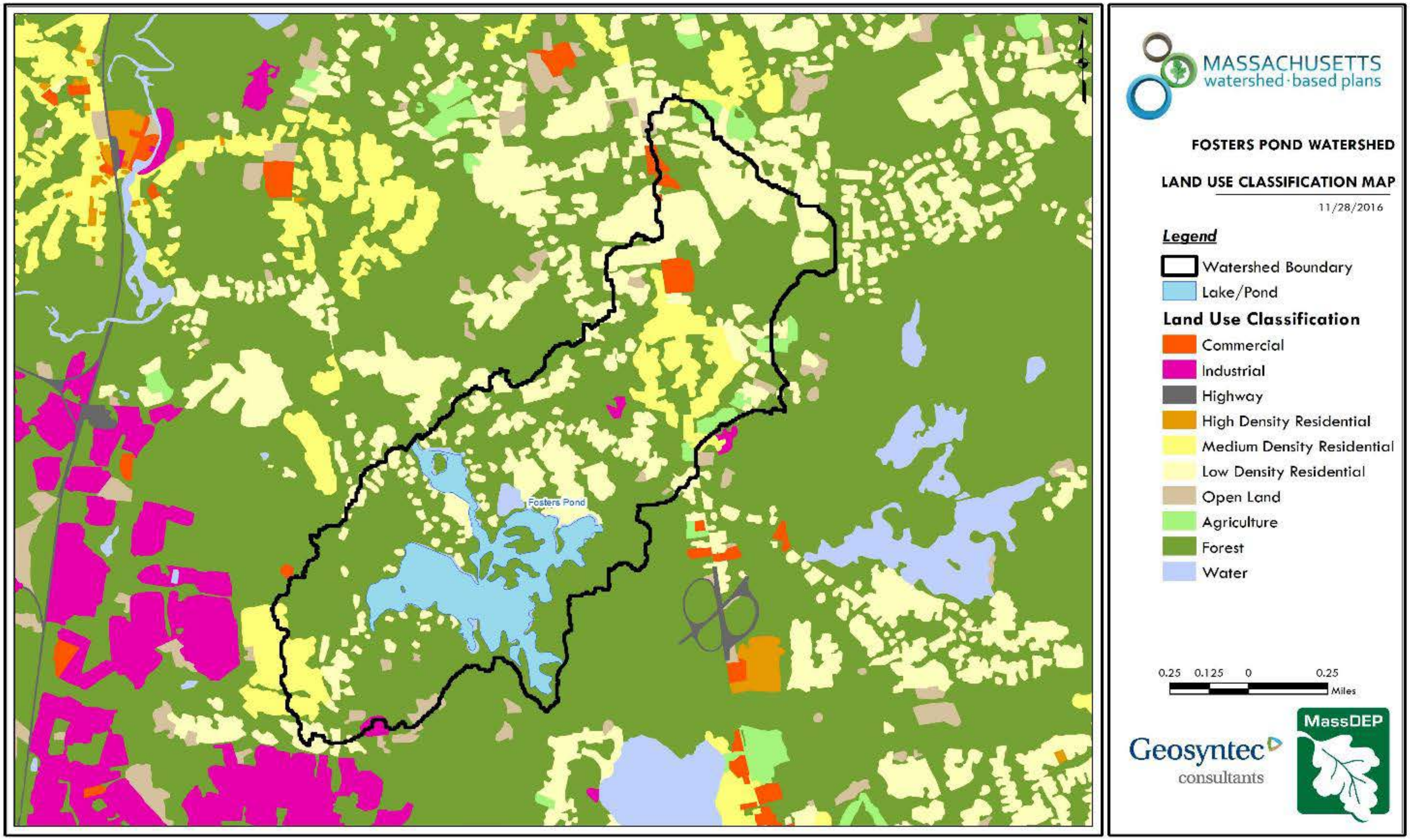


Figure A-2: Watershed Land Use Map (MassGIS, 2009b; MassGIS, 1999; MassGIS, 2001; USGS, 2016)

Watershed Impervious Cover

There is a strong link between impervious land cover and stream water quality. Impervious cover includes land surfaces that prevent the infiltration of water into the ground, such as paved roads and parking lots, roofs, basketball courts, etc. **Impervious areas that are directly connected (DCIA)** to receiving waters (via storm sewers, gutters, or other impervious drainage pathways) produce higher runoff volumes and transport stormwater pollutants with greater efficiency than disconnected impervious cover areas which are surrounded by vegetated, pervious land. Runoff volumes from disconnected impervious cover areas are reduced as stormwater infiltrates when it flows across adjacent pervious surfaces.

An estimate of DCIA for the watershed was calculated based on the Sutherland equations. USEPA provides guidance (USEPA, 2010) on the use of the Sutherland equations to predict relative levels of connection and disconnection based on the type of stormwater infrastructure within the **total impervious area (TIA)** of a watershed. Within each subwatershed, the total area of each land use were summed and used to calculate the percent TIA.

Estimated TIA in the watershed: 11.6%
(Proximal: 7.7%; Frye's Brook: 14.7%)

Estimated DCIA in the watershed: 6.1 %
(Proximal: 3.8%; Frye's Brook: 7.4%)

The TIA areas are presented on Figure A-3. The relationship between TIA and water quality can generally be categorized as follows (Schueler et al. 2009) (Table A-8). Note that the below table is most instructive for evaluation of the Frye's Brook Watershed with 7.4% TIA) rather than the proximal watershed which encompasses Foster's Pond.

Table A-8: Relationship between Total Impervious Area (TIA) and water quality (Schueler et al. 2009)

% Watershed Impervious Cover	Stream Water Quality (i.e., Frye's Brook)
0-10%	Typically high quality, and typified by stable channels, excellent habitat structure, good to excellent water quality, and diverse communities of both fish and aquatic insects.
11-25%	These streams show clear signs of degradation. Elevated storm flows begin to alter stream geometry, with evident erosion and channel widening. Streams banks become unstable, and physical stream habitat is degraded. Stream water quality shifts into the fair/good category during both storms and dry weather periods. Stream biodiversity declines to fair levels, with most sensitive fish and aquatic insects disappearing from the stream.
26-60%	These streams typically no longer support a diverse stream community. The stream channel becomes highly unstable, and many stream reaches experience severe widening, downcutting, and streambank erosion. Pool and riffle structure needed to sustain fish is diminished or eliminated and the substrate can no longer provide habitat for aquatic insects, or spawning areas for fish. Biological quality is typically poor, dominated by pollution tolerant insects and fish. Water quality is consistently rated as fair to poor, and water recreation is often no longer possible due to the presence of high bacteria levels.
>60%	These streams are typical of "urban drainage", with most ecological functions greatly impaired or absent, and the stream channel primarily functioning as a conveyance for stormwater flows.

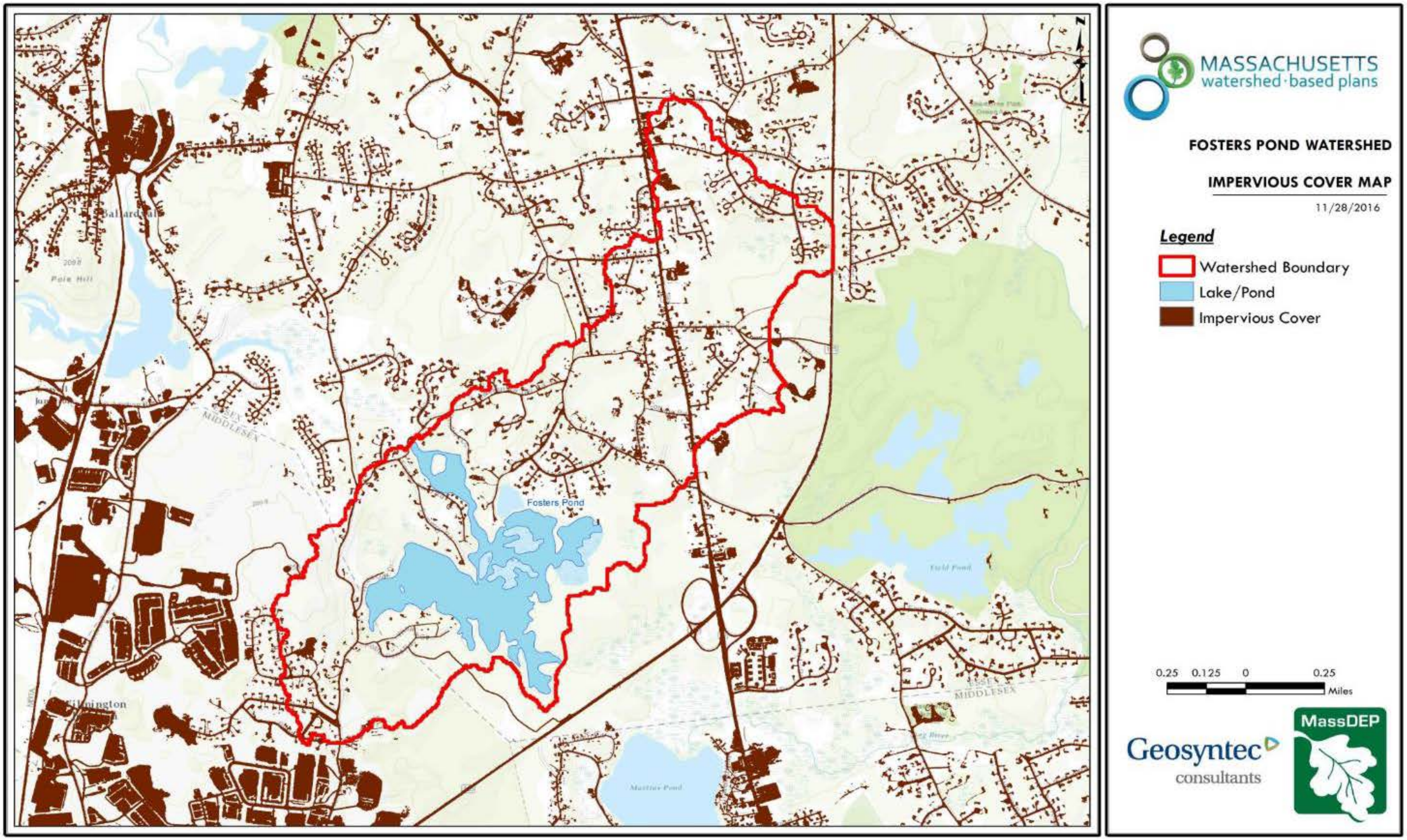


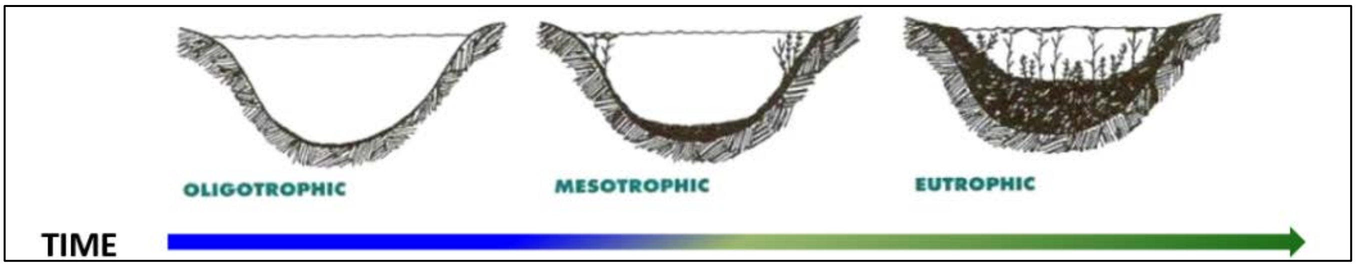
Figure A-3: Watershed Impervious Surface Map (MassGIS, 2009b; MassGIS, 1999; MassGIS, 2001; USGS, 2016)

Land Use Interpretation

A comparative review of land use designations, estimated impervious area, and DCIA indicates that the Frye's Brook watershed generally has a higher level of development and could potentially be contributing to a disproportionate amount of pollutant loading to Foster's Pond as compared to the proximal watershed.

7. Pollutant Loading and Trophic Response

Eutrophication is the gradual process of nutrient enrichment in aquatic ecosystems such as lakes and ponds that results in increased biological productivity. Eutrophication occurs naturally as ponds become more biologically productive over geological time, but this process is often accelerated by human activities in the watershed. Nutrients that contribute to eutrophication can come from many natural and anthropogenic sources, such as fertilizers applied to residential lawns and agricultural fields; septic systems; deposition of nitrogen from the atmosphere; erosion of soil containing nutrients; and sewage treatment plant discharges. Land development not only increases the sources of nutrients, but also decreases opportunities for natural attenuation (e.g. uptake by vegetation) of such nutrients before they can reach a water body.



Eutrophication is the natural process by which nutrients, organic matter and sediments gradually accumulate within a water body, resulting in decreased depth and increased biological productivity. This process can be greatly accelerated by human activities in the watershed.

Nutrients such as phosphorus and nitrogen can stimulate abundant growth of algae and rooted plants in water bodies. Over time, this enhanced plant growth leads to reduced dissolved oxygen in the water, as plant material decomposes and consumes oxygen. Phosphorus is typically the "limiting nutrient" for freshwater lakes, which means that plant productivity is most often controlled by the supply of this nutrient. As such, increases in phosphorus load in a lake watershed are closely correlated with increases in plant productivity and accelerated eutrophication.

To understand the magnitude of the role that phosphorus plays in the productivity of Foster's Pond, Geosyntec calculated an annual phosphorus budget by considering various phosphorus sources within the watershed, including non-point-source pollution from stormwater runoff (i.e., land-use based), septic system discharge, and aerial deposition as discussed in the below sections.

Land-Use Based Phosphorus Loading

The land use data (MassGIS, 2009b) was intersected with impervious cover data (MassGIS, 2009a) and United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) soils data (USDA NRCS and MassGIS, 2012) to create a combined land use/land cover grid. The grid was used to sum the total area of each unique land use/land cover type.

The amount of DCIA was estimated using the Sutherland equations as described above and any reduction in impervious area due to disconnection (i.e., the area difference between TIA and DCIA) was assigned to the pervious D soil category for that land use to simulate that some infiltration will likely occur after runoff from disconnected impervious surfaces passes over pervious surfaces.

Pollutant loading for key nonpoint source pollutants in the watershed was estimated by multiplying each land use/cover type area by its pollutant load export rate (PLER). The PLERs are an estimate of the annual total pollutant load exported via stormwater from a given unit area of a particular land cover type. The PLER values for TN, TP and TSS were obtained from USEPA (Voorhees, 2016b) (see documentation provided in Appendix A) as follows:

$$L_n = A_n * P_n$$

Where L_n = Loading of land use/cover type n (lb/yr); A_n = area of land use/cover type n (acres); P_n = pollutant load export rate of land use/cover type n (lb/acre/yr)

The estimated land-use based phosphorus load to Foster's Pond is 208 pounds per year, as presented in Table A-8 of the Foster's Pond WBP and summarized below. A comparative review of pollutant loading between subwatershed areas indicates that, on a per acre basis, pollutant loading from the Frye's Brook subwatershed is disproportionally higher than from the Proximal subwatershed. The Frye's Brook subwatershed comprises approximately 46% of the entire watershed, but contributes approximately 60% of all estimated land-use based phosphorus loading to Foster's Pond. It should also be noted that 88.3 pounds (42%) of the watershed's total phosphorus load (208 pounds) is estimated to come from forested areas. Most phosphorus generated from forested areas is a result of natural processes such as decomposition of leaf litter and other organic material. Such areas generally represent a "best case scenario" with regard to phosphorus loading, meaning that nearly half of the watershed is unlikely to provide opportunities for nutrient load reductions through best management practices.

Table A-9: Estimated Pollutant Loading for Key Nonpoint Source Pollutants

Land Use Type	Proximal Watershed Loading* (lbs/yr)			Frye's Brook Watershed Loading* (lbs/yr)		
	Total Phosphorus (TP)	Total Nitrogen (TN)	Total Suspended Solids (TSS)	Total Phosphorus (TP)	Total Nitrogen (TN)	Total Suspended Solids (TSS)
Agriculture	0.0	0.0	0.0	4.8	29.2	893.9
Commercial	0.0	0.1	2.2	7.5	66.7	1667.0
Forest	53.1	286.6	18757.4	35.2	193.2	15859.7
High Density Residential	0.0	0.0	0.0	0.0	0.0	0.0
Highway	0.0	0.0	0.0	0.0	0.0	0.0
Industrial	0.7	6.2	155.2	0.8	7.2	181.2
Low Density Residential	20.7	200.2	5587.1	50.9	511.9	13955.0
Medium Density Residential	9.8	82.6	2305.5	22.2	189.1	5316.1
Open Land	0.7	6.7	195.2	1.4	12.8	583.4
TOTAL	**85.1**	**582.3**	**27002.6**	**122.8**	**1010.3**	**38456.5**
*Pollutant loading estimates do not consider loads from point sources or septic systems.						
GRAND TOTALS: Total Phosphorus = 208 Pounds/yr - Total Nitrogen = 1592 Pounds/yr - Total Suspended Solids = 33 Tons/yr						

Phosphorus from Septic Systems

Septic systems allow treated wastewater effluent, which is rich in phosphorus and other nutrient content, to leach into the groundwater and potentially migrate to the pond. Because phosphorus tends to become bound to soil particles, the distance it can travel may be relatively short. For this reason, it is customary to only include septic systems in the near shore area (within 200 feet of shoreline) when calculating an annual septic system phosphorus load.

The Foster's Pond Corporation provided data associated with septic systems within 200 feet of the pond. The data included 67 homes in Andover and an additional 7 homes in Wilmington in the near shore area that are served by septic systems. Based on the provided data, Geosyntec calculated an annual phosphorus load from septic systems of 21 pounds per year using the following formula:

$$S = \sum_{i=0}^{h} B_i \cdot n_i \cdot Q_c \cdot m_i \cdot P_w \cdot \theta$$

Where:

S is the total P load from septic systems (lbs.);

h is the total number of homes considered in the inventory;

B_i is the number of bedrooms served by the system;

n_i is the average number of persons per bedroom (0.85, determined from past experience in similar areas and confirmed with census data);

Q_c is the per-capita daily water use (69.3 gal/person/day, from the USEPA Onsite Wastewater Treatment Systems Manual, 2002);

m_i is the number of months that the home is occupied (assumed year-round occupation);

P_w is the concentration of phosphorus in wastewater (10 mg/L, from the USEPA Onsite Wastewater Treatment Systems Manual);

θ is the fraction of phosphorus removal attributed to the septic system and leach field (0.94[5]).

The number of bedrooms per home was not available for homes located in Wilmington and was estimated based on home type using the Andover data as a basis.

Phosphorus from Aerial Deposition

Atmospheric deposition of phosphorus is an estimate of the load of phosphorus delivered through wet or "dryfall" precipitation depositing phosphorus-containing particles directly on the surface of Foster's Pond. Deposition rates were determined from published literature (Reckhow, 1980). The annual atmospheric deposition load was calculated assuming a deposition rate of 0.24 lb. P/ac/yr, for a total atmospheric load of 26 lb. P/yr.

Total External Phosphorus Load

The total external phosphorus load into Foster's Pond was calculated to be 255 pounds per year (116 kg) from the above sources as summarized below

[5] This factor represents a phosphorus removal percentage after soil absorption and is based on past experience developing phosphorus budgets for other similar systems and from prior literature reviews (e.g., Gillion and Patmont, 1983).

- Land Use: 208 pounds per year
- Septic Systems: 21 pounds per year
- Aerial Deposition: 26 pounds per year
- **Total:** 255 pounds per year.

Therefore, most phosphorus loading (82%) is estimated to be comprised of surface water runoff and discharge from the surrounding stormwater system (Figure A-4).

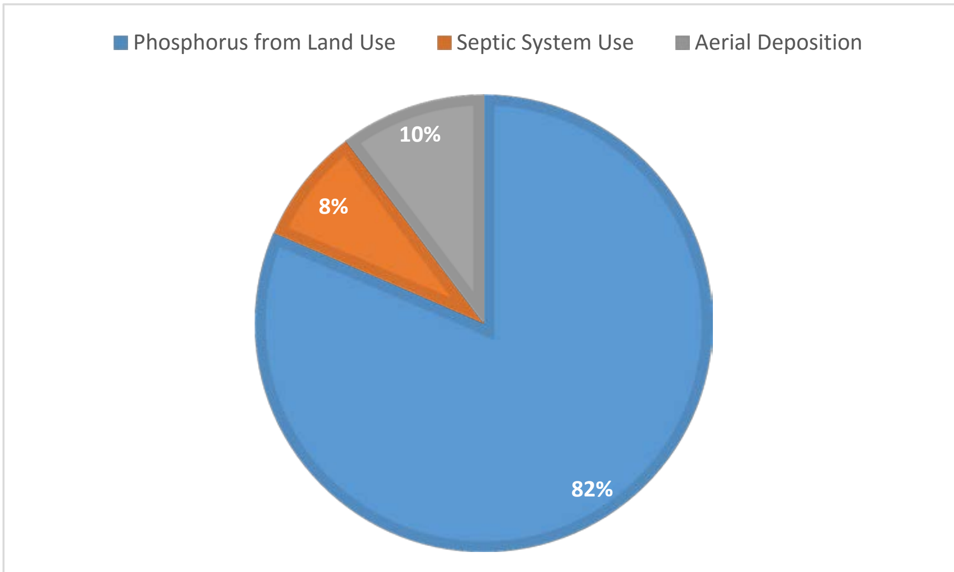


Figure A-4: Summary of Annual External Phosphorus Load to Foster's Pond

Trophic Response to Phosphorus Loading

In-lake phosphorus response models are commonly used to predict in-lake phosphorus concentrations as a function of annual phosphorus loading, mean lake depth, and hydraulic residence time. The models are useful for understanding the relationships between current phosphorus loading and in-lake concentration, as well as for estimating in-lake concentrations under hypothetical scenarios, such as future buildout. One of the most commonly used in-lake response models is the Vollenweider model, which predicts an average annual in-lake phosphorus concentration. Phosphorus concentrations predicted by the Vollenweider model assume that the lake is uniformly mixed, such as at spring turnover. The Vollenweider model is based on a five-year study of approximately 200 waterbodies in Europe, North America, Japan and Australia (Vollenweider and Schweiz, 1975).

The Vollenweider Equation is provided below, with calculations for Foster's Pond based on the phosphorus loading estimate discussed above, including phosphorus from stormwater runoff, septic systems, and aerial deposition. The equation parameters and the values specific to Foster's Pond are presented by Table A-9. The Vollenweider Equation is:

$$p_v = \frac{L_p}{\left(q_s\left(1+\sqrt{\tau_w}\right)\right)} = \frac{261}{4.83\left(1+\sqrt{3.22}\right)} = 19.3\ \mu\text{g/L}$$

where:

p_v = mean in-lake phosphorus concentration (mg/L) estimated by Vollenweider equation;

L_p = annual phosphorus load/lake area, (grams/m^2/year);

τ_w = hydraulic residence time (yr);

q_s = hydraulic overflow rate=mean depth /hydraulic residence time (m/yr)= z/τ_w;

z = average depth (m)

Table A-9 Vollenweider Model Parameters and Assumptions

Parameter		Value	Units	Source/Assumption
W	Total P Loading Rate	116	Kg/yr	Calculated Pollutant Load Value
V	Volume	663,612	m^3	2016 GEI Dam Inspection Report
z	Average Lake Depth	1.5	m	Calculated Value
Q[6]	Annual Discharge	2,138,619	m^3/yr	WBP Tool Archived Data
A_s	Lake Area	442,726	m^2	WBP Tool Archived Data
L	Areal Loading Rate	261	mg/m^2	Calculated Value
q_s	Hydraulic Overflow Rate	4.83	m/yr	Calculated Value
τ_w[7]	Hydraulic Residence Time	3.22	yr^{-1}	Calculated Value

Based on the estimated annual external phosphorus load of 255 pounds per year, the Vollenweider equation predicts an in-lake phosphorus concentration of 19.3 µg/L when Foster's Pond is in a fully mixed state. This predicted concentration is below the previously discussed USEPA Gold Book Standard of 25 µg/L, which is also the threshold (lower limit) concentration for classification as a eutrophic pond. As previously discussed, FPC water quality sampling data indicates an average phosphorus concentration of 21 µg/L (2004-2017 data for all sampling locations), with an average of 23.5 µg/L if Dug Pond data is excluded. Therefore, results suggest that the Vollenweider equation provides a reasonable estimate of in-lake phosphorus dynamics, but is slightly underpredicting actual conditions.

Note that the Vollenweider equation assumes uniform mixing (i.e., spring and fall turnover) while most phosphorus measurements were taken during the summer months when phosphorus concentrations are expected to be somewhat elevated. The Element I (Monitoring) section of this report provides recommendations on future monitoring efforts to provide additional calibration and validation of the model. Once calibrated, the model can be used to provide more precise estimates of in-lake phosphorus concentrations and estimates of the pond's response to future decreases (e.g., implementation of nutrient control BMPs) or increases (e.g., due to land development) in the watershed's phosphorus load.

Also note that a pollutant load reduction target is proposed as part of Element B of the WBP. The relationship between flushing rate, external phosphorus load, and in-lake phosphorus concentration presented by the Vollenweider model has implications for future pond management. Based on the modeled annual phosphorus load estimate of 255 pounds per year, the Vollenweider equation predicts that an annual load reduction of 6 pounds per year would be required to decrease the in-pond phosphorus concentration by 1 µg/L. This relationship is depicted by Figure A-5. For example, a reduction in annual Phosphorus loading of 10% would reduce loading by approximately by 25 pounds and would result in an estimated in-lake phosphorus concentration of 17.4 µg/L.

[6] Annual discharge estimated per methodology outlined in Element B, Section 2.

[7] Residence time based on estimated annual discharge.

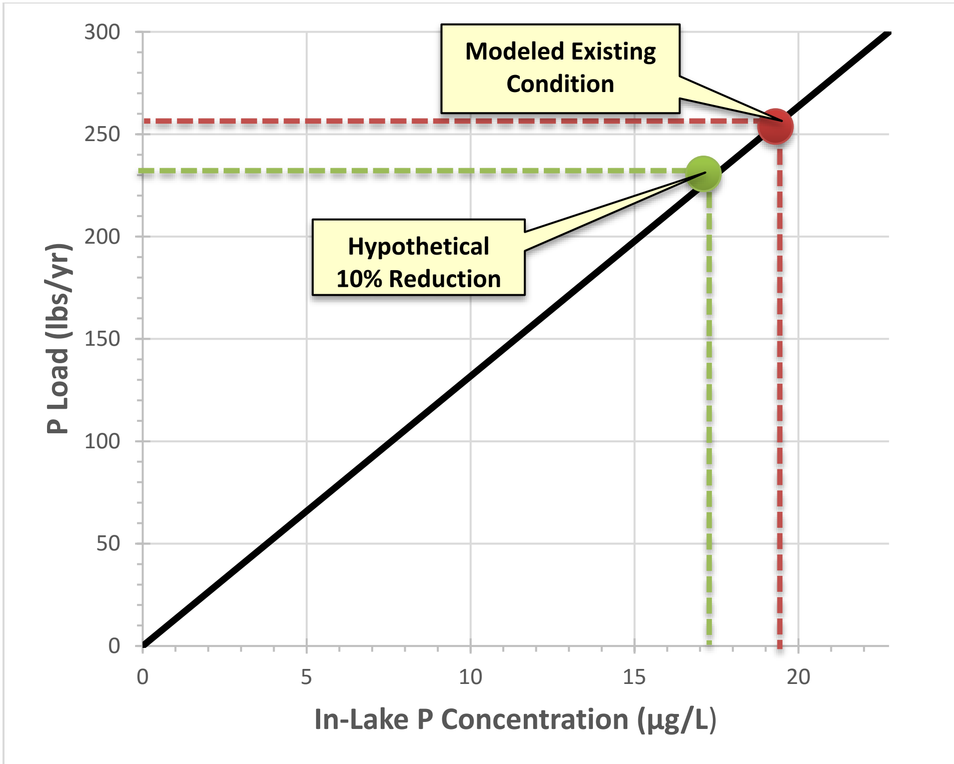


Figure A-5: Foster's Pond Vollenweider Relationship Between Phosphorus Loading and In-Lake Concentration

Element B: Determine Pollutant Load Reductions Needed to Achieve Water Quality Goals

Element B of your WBP should:

Determine the pollutant load reductions needed to achieve the water quality goals established in Element A. The water quality goals should incorporate Total Maximum Daily Load (TMDL) goals, when applicable. For impaired water bodies, a TMDL establishes pollutant loading limits as needed to attain water quality standards.

1. Estimated Pollutant Loads

Table B-1 lists estimated pollutant loads for the following primary nonpoint source (NPS) pollutants: total phosphorus (TP), total nitrogen (TN), total suspended solids (TSS). These estimated loads are based on the pollutant loading analysis presented in Section 5 of Element A.

2. Water Quality Goals

Water quality goals for primary NPS pollutants are listed in Table B-1 based on the following:

- TMDL water quality goals (if a TMDL exists for the water body);
- For all water bodies, including impaired waters that have a pathogen TMDL, the water quality goal for bacteria is based on the Massachusetts Surface Water Quality Standards (314 CMR 4.00, 2013) that apply to the Water Class of the selected water body.
- If the water body does not have a TMDL for TP, a default target TP concentrations is provided which is based on guidance provided by the USEPA in Quality Criteria for Water (1986), also known as the "Gold Book". Because there are no similar default water quality goals for TN and TSS, goals for these pollutants are provided in Table B-1 only if a TMDL exists or alternate goal(s) have been optionally established by the WBP author.
- According to the USEPA Gold Book, total phosphorus should not exceed 50 ug/L in any stream at the point where it enters any lake or reservoir. The water quality loading goal was estimated by multiplying this target maximum phosphorus concentration (50 ug/L) by the estimated annual watershed discharge for the selected water body. To estimate the annual watershed discharge, the mean flow was used, which was estimated based on United States Geological Survey (USGS) "Runoff Depth" estimates for Massachusetts (Cohen and Randall, 1998). Cohen and Randall (1998) provide statewide estimates of annual Precipitation (P), Evapotranspiration (ET), and Runoff (R) depths for the northeastern U.S. According to their method, Runoff Depth (R) is defined as all water reaching a discharge point (including surface and groundwater), and is calculated by:

  $$P - ET = R$$

  A mean Runoff Depth R was determined for the watershed by calculating the average value of R within the watershed boundary. This method includes the following assumptions/limitations:

a. For lakes and ponds, the estimate of annual TP loading is averaged across the entire watershed. However, a given lake or reservoir may have multiple tributary streams, and each stream may drain land with vastly different characteristics. For example, one tributary may drain a highly developed residential area, while a second tributary may drain primarily forested and undeveloped land. In this case, one tributary may exhibit much higher phosphorus concentrations than the average of all streams in the selected watershed.
b. Phosphorus is loading is based on the factors listed in Element A, Section 7 including land use, septic systems, and aerial deposition. Internal phosphorus loading was not considered as part of this estimate.

Table B-1: Pollutant Load Reductions Needed

Pollutant	Existing Estimated Total Load	Water Quality Goal	Required Load Reduction
Total Phosphorus	255 lbs/yr	230 lbs/yr (See Below)	25 lb/yr (See Below)
Total Nitrogen	1591 lbs/yr		
Total Suspended Solids	33 ton/yr		
Bacteria	*MSWQS for bacteria are concentration standards (e.g., colonies of fecal coliform bacteria per 100 ml), which are difficult to predict based on estimated annual loading)*	Class B. **Class B Standards** • Public Bathing Beaches: For E. coli, geometric mean of 5 most recent samples shall not exceed 126 colonies/ 100 ml and no single sample during the bathing season shall exceed 235 colonies/100 ml. For enterococci, geometric mean of 5 most recent samples shall not exceed 33 colonies/100 ml and no single sample during bathing season shall exceed 61 colonies/100 ml; • Other Waters and Non-bathing Season at Bathing Beaches: For E. coli, geometric mean of samples from most recent 6 months shall not exceed 126 colonies/100 ml (typically based on min. 5 samples) and no single sample shall exceed 235 colonies/100 ml. For enterococci, geometric mean of samples from most recent 6 months shall not exceed 33 colonies/100 ml, and no single sample shall exceed 61 colonies/100 ml.	

3. Recommended Load Reduction

Based on results from the Trophic Status Modeling (See Element A), the existing phosphorus load to Foster's Pond is estimated at 255 pounds per year with 82% coming from Land Use contributions. The model estimates that the resulting in-lake phosphorus concentration is 19.3 µg/L, which is typically representative of mesotrophic conditions. To further improve water quality, a long-term reduction on annual phosphorus loading of 10% is proposed. This would reduce annual loading by approximately 25 pounds and would result in an estimated in-lake phosphorus concentration of 17.4 µg/L. As discussed by Element HI, it is recommended that this goal be re-evaluated and adaptively adjusted based on future refinements to the model and/or based on future sampling results.

Element C: Describe management measures that will be implemented to achieve water quality goals

ELEMENT C: A description of the nonpoint source management measures needed to achieve the pollutant load reductions presented in Element B, and a description of the critical areas where those measures will be needed to implement this plan.

1. Field Watershed Investigation

Geosyntec conducted a field investigation of the Foster's Pond Watershed ("Watershed") on April 28, 2017 in Andover Massachusetts. Mr. Stephen Cotton and Ms. Amy Janovsky of the Foster's Pond Corporation were present during the initial portion of the field investigation to orient Geosyntec with the Watershed and identify areas of interest. Based on the results of this field investigation and assessment, the following pages present potential best management practices (BMPs) and restoration practices that relate to storm water management and phosphorus load reduction for the Watershed.

The recommended implementation sites discussed in this section are not intended to be an all-inclusive listing of potential stormwater improvements in the Watershed. Rather, these recommendations are representative examples of potential stormwater improvements and retrofits that could be implemented at numerous sites throughout the Watershed. All developed portions of the Watershed were visited, but emphasis was generally placed on those areas with direct conveyance to Foster's Pond (e.g., Frye's Brook, intermittent tributaries in Proximal Watershed, stormwater infrastructure, etc.).

Figure C-1 shows the location of each proposed BMP site.

2. Primary BMP Recommendations

The BMP improvement sites described on the following pages were identified during Geosyntec's field investigations. The design goal for the proposed BMPs would be to size the BMP to treat and infiltrate the water quality volume to the maximum extent practicable. The water quality volume is defined in the Massachusetts Stormwater Handbook as the volume equal to 0.5 inches of runoff times the total impervious area within the drainage area of the BMP. However, each proposed BMP should be designed to achieve the most treatment that is practical given the size and logistical constraints of the site.

Each BMP site description includes:

- A site summary that describes current conditions and stormwater drainage patterns;
- A description of proposed improvements;
- Estimated costs that represent installed contractor construction costs (i.e. capital costs); other potential costs (e.g., engineering, O&M, and permitting); and
- Estimated pollutant load reduction for the proposed BMP.

Planning level cost estimates and pollutant load reduction estimates provided below were based off information obtained in the following sources and were also adjusted to 2016 values using the Consumer Price Index (CPI) (United States Bureau of Labor Statistics, 2016):

- Geosyntec Consultants, Inc. (2014);
- Geosyntec Consultants, Inc. (2015);
- King and Hagen (2011);
- Leisenring, et al. (2014);
- King and Hagen (2011);
- MassDEP (2016a);
- MassDEP (2016b);
- University of Massachusetts, Amherst (2004);
- Voorhees (2015);
- Voorhees (2016a);
- Voorhees (2016b);

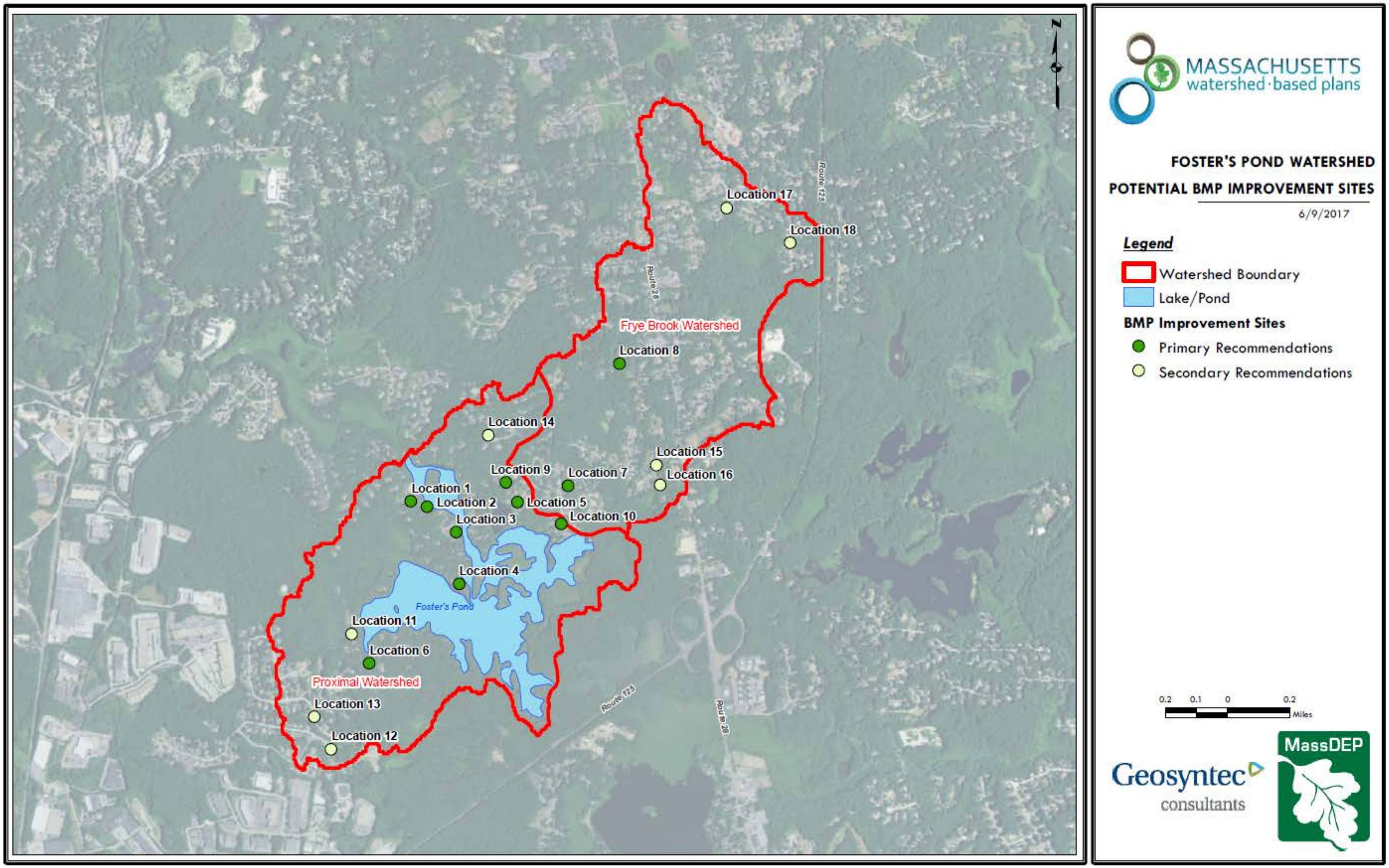


Figure C-1. Potential BMP Improvement Sites

Site 1: Foster's Pond Road

Intersection with Pomeroy Road

Site Summary: Photo 1-1

Two catch basins collect surface runoff from the northwestern portion of Foster's Pond Road and from the northernmost portion of Pomeroy Road. Runoff from the catch basins is conveyed to the Pond through an outfall located approximately 300 feet downstream (Site 2).

Proposed Improvement: Photo 1-2, Image 1-3

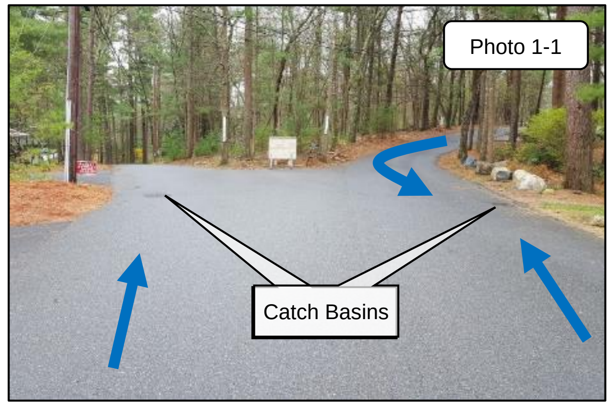
Install 200 square foot bioretention cells within the right-of-way adjacent to each catch basin. The existing catch basins would be used as an overflow during larger storm events.

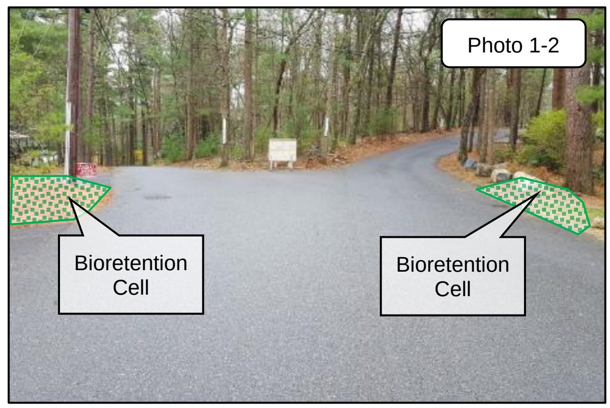
Expected O&M:

Remove accumulated sediment from bioretention cells annually and maintain/replace plants as needed every two years. Coordinate snow plow to minimize snow dumping.

Estimated Performance and Cost:

Sizing Characteristics	
Drainage Area (acres)	0.69
Impervious Area (%)	59
Estimated Load Reduction (lb/yr)	
TN (lbs/yr)	2.9
TP (lbs/yr)	0.27
TSS (lbs/yr)	137.9
Estimated Costs ($)	
Total[8]	$11,463





[8] Estimated total costs include hard costs (e.g., construction and materials) and soft costs (e.g., engineering, permitting, O&M). Refer to Table D-1 of Element D for a breakdown of costs for each recommendation.

Image 1-3

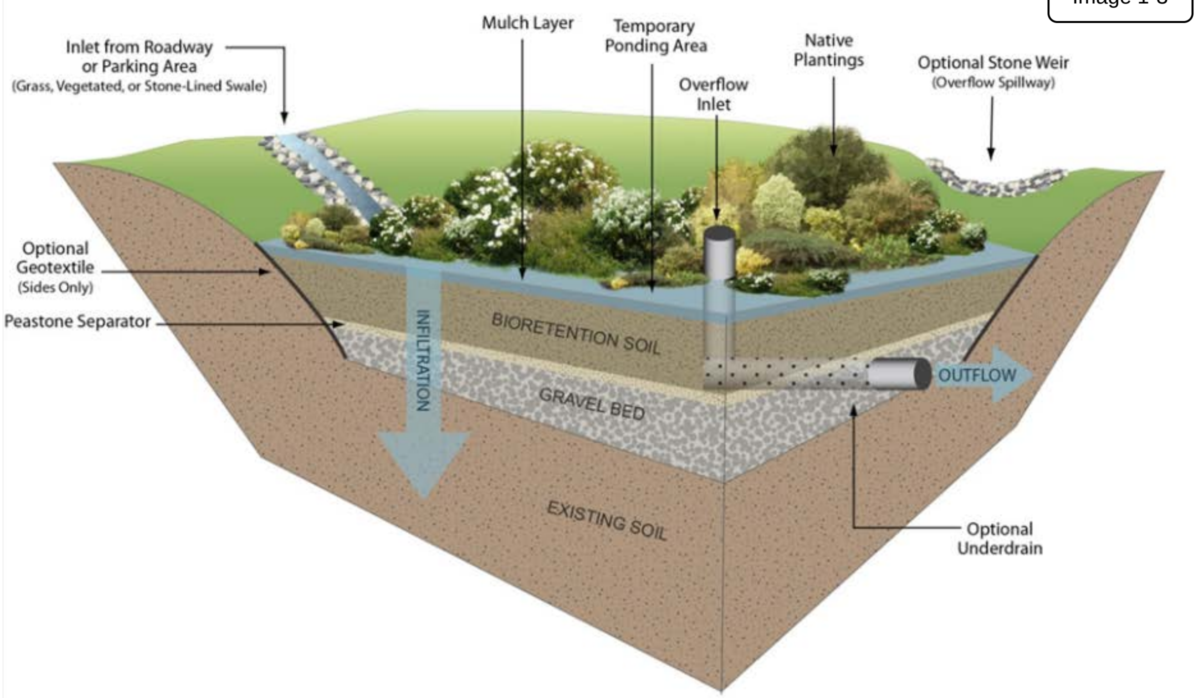


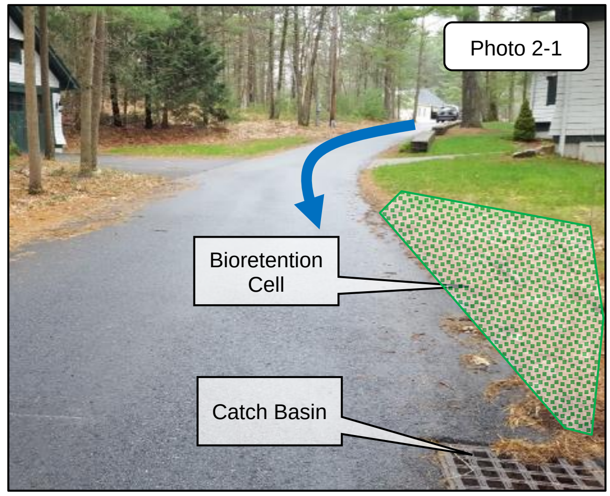
Image 1-3 is a cross section schematic of a typical bioretention cell. Bioretention cells are shallow landscaped depressions that incorporate plantings and engineered soil with a high porosity and infiltration capacity. Bioretention cells control stormwater runoff volume by providing storage, reducing peak discharge, and removing pollutants through physical, chemical, and biological processes occurring in plants and soil (MA Stormwater Handbook).

Site 2: Foster's Pond Road

Between 12 and 15 Foster's Pond Road

Site Summary: Photo 2-1

A catch basin collects surface runoff from a relatively steep section of Foster's Pond Road, just downstream of Site 1. The catch basin discharges to the Pond through a lower opening (but does not have a formal outfall). Note that the discharge point was not visited during the assessment.



This improvement would be most beneficial if coupled with upstream Site 1 improvements and would result in less pollutant loading to the outfall.

Proposed Improvements: Photo 2-1

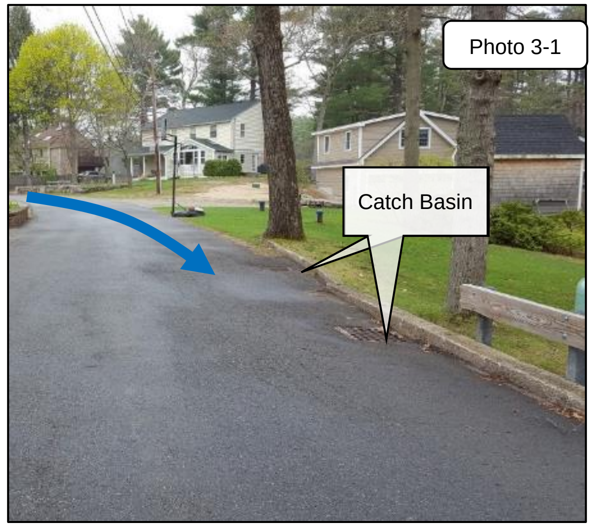
- Install 500 square foot bioretention cell within the right-of-way upstream of the existing catch basin. The catch basin would be used as an overflow during larger storm events.
- Locate the downstream outfall and inspect for signs of previous scour or erosion to determine if stabilization or outlet protection (e.g., energy dissipation) would be beneficial.

Expected O&M: Remove accumulated sediment from bioretention cell annually and maintain/replace plants as needed every two years. Coordinate snow plow to minimize snow dumping

Sizing Characteristics	
Drainage Area (acres)	0.96
Impervious Area (%)	19
Estimated Load Reduction (lb/yr)	
TN (lbs/yr)	1.7
TP (lbs/yr)	0.15
TSS (lbs/yr)	75.87
Estimated Costs ($)	
Total	$15,852

Site 3: Foster's Pond Road

Adjacent to 26 Foster's Pond Road



Site Summary: Photo 3-1

Two catch basins collect surface runoff from Foster's Pond Road, downstream of Site 2. The catch basins discharge to the Pond through two adjacent outfalls, each approximately 12-inches in diameter. The outfalls were not visited during the assessment, but a resident indicated that previous sedimentation has been observed.

Proposed Improvements: Image 3-2

- There are two large trees near the catch basins so excavation for installation of infiltration feature such as a bioretention cell on the side of the road would likely be infeasible without damage to tree roots. Therefore, we recommend that hydrodynamic separators be installed in the existing catch basins to provide treatment of sediment-laden runoff.
- Locate downstream outfalls (on private property) and inspect for signs of previous scour or erosion to determine if stabilization or outlet protection (e.g., energy dissipation) would be beneficial.

Expected O&M: Annually Inspect and remove accumulated trash, debris, and sediment.

Wetland Permitting: As a replacement/ upgrade of existing stormwater infrastructure, no WPA permitting is anticipated.

Sizing Characteristics	
Drainage Area (acres)	0.87
Impervious Area (%)	29
Estimated Load Reduction (lb/yr)	
TN (lbs/yr)	-
TP (lbs/yr)	-
TSS (lbs/yr)	32.2
Estimated Costs ($)	
Total	$19,800

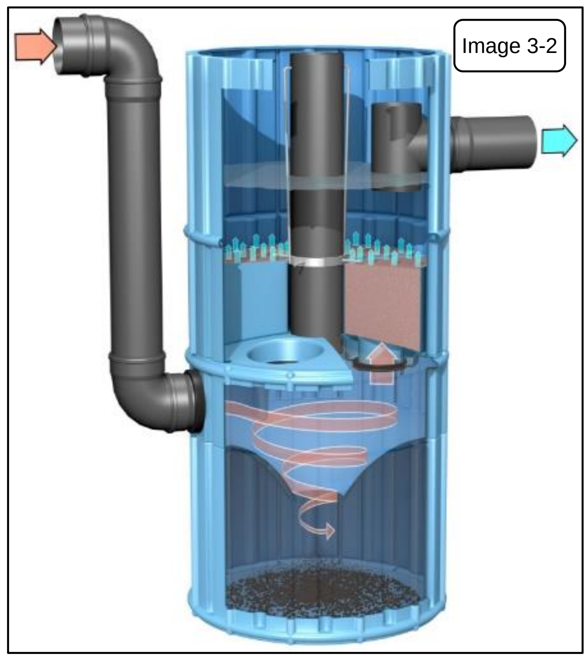


Image 3-2 is a schematic of a typical hydrodynamic separator. A hydrodynamic separator is a stormwater management technology that treats stormwater primarily by using gravity to remove particles and phase separation to remove materials such as oil and grease from the water matrix.

Site 4: End of Pomeroy Road

Adjacent to 23 Pomeroy Road

Site Summary: Photos 4-1, 4-2

A steep hill drains to a natural drainage ditch that outfalls to the Pond. Accumulated sand was observed at the mouth. The channel was not stabilized and is an additional source of pollutant loading to the Pond.

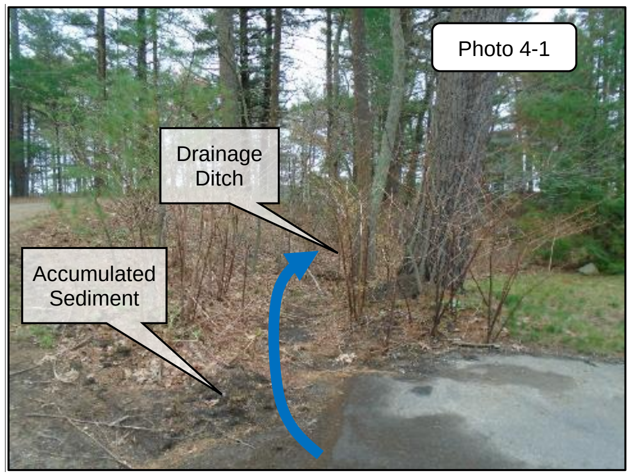
Proposed Improvements: Photo 4-3

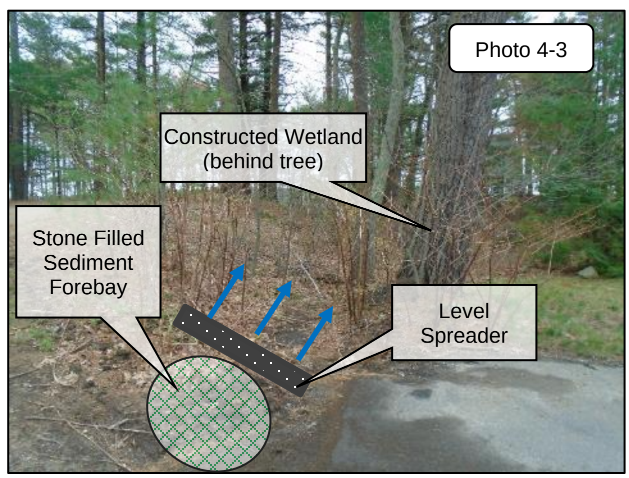
- Install level spreader and inlet protection / sediment forebay at the mouth of the ditch to dissipate concentrated runoff.
- Install 1,500 square foot stormwater constructed wetland to collect and treat stormwater prior to discharge to the Pond.
- Locate outfall to Pond (on private property) and inspect for erosion to determine if stabilization or outlet protection would be beneficial.

Expected O&M: Inspect and maintain the constructed wetland including inlets and outlets annually for debris, sediment, and erosion.

Wetland Permitting: As a project with minor buffer zone disturbances, WPA permitting is expected to require submittal of an ANOI.

Sizing Characteristics	
Drainage Area (acres)	4.25
Impervious Area (%)	15
Estimated Load Reduction (lb/yr)	
TN (lbs/yr)	7.0
TP (lbs/yr)	0.64
TSS (lbs/yr)	319.5
Estimated Costs ($)	
Total	$71,894





Constructed stormwater wetlands are stormwater wetland systems that maximize the removal of pollutants from stormwater runoff through wetland vegetation uptake, retention and settling (Massachusetts Stormwater Handbook).

Site 5: Snowberry Road

End of Cul-de-sac

Site Summary: Photos 5-1, 5-2, 5-3

The road slopes to a catch basin at the end of the cul-de-sac, which drains to a 12-inch concrete outfall located 10 feet from the Pond. The outfall was approximately half full of sediment and erosion leading into the Pond was observed.

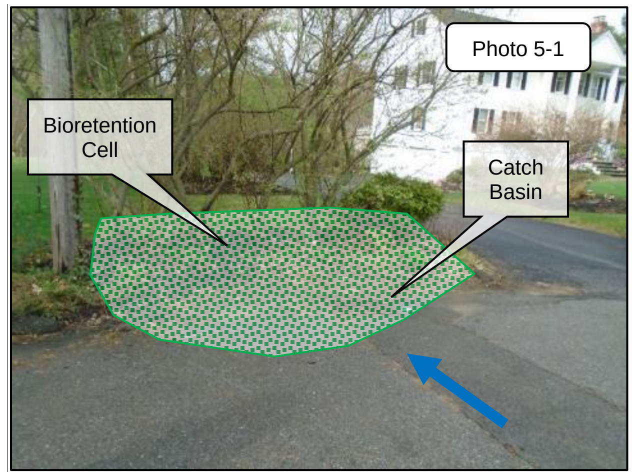
Proposed Improvements: Photos 5-1 and 5-3

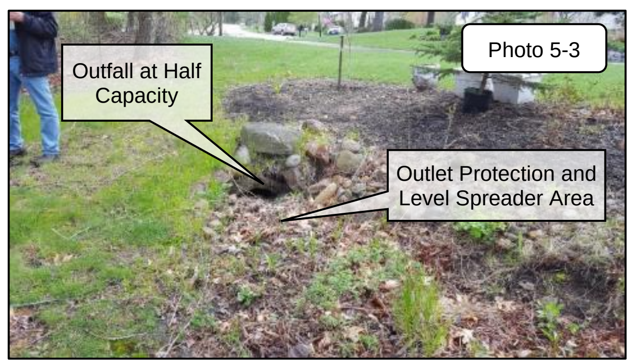
Remove asphalt surrounding existing catch basin (where feasible) and install 200-square foot bioretention cell using existing catch basin as an overflow. Existing landscaping would require disturbance. Coordinate with homeowner and install stone outlet protection with level spreader to minimize concentrated discharge and erosion.

Expected O&M: Remove accumulated sediment from bioretention cell and outlet protection annually and maintain/replace plants as needed every two years. Coordinate snow plow to minimize snow dumping.

Wetland Permitting: This project involves minor activity within the buffer zone to stabilize and existing outlet area and could be permitted through a Negative Determination under a WPA request for Determination of Applicability.

Sizing Characteristics	
Drainage Area (acres)	2.75
Impervious Area (%)	27
Estimated Load Reduction (lb/yr)	
TN (lbs/yr)	1.7
TP (lbs/yr)	0.15
TSS (lbs/yr)	76.35
Estimated Costs ($)	
Total	$12,276





Goose droppings were observed within the site vicinity on the adjacent homeowner's driveway within the easement to the outfall.

Site 6: Willard Circle

Upstream of intermittent stream crossing

Site Summary: Photos 6-1, 6-2

Runoff sheets off the shoulder of the dirt road and into a wetland area adjacent to an intermittent stream (just upstream of a 6-inch metal culvert crossing). Erosion was observed in multiple locations along the bank and could result in pollutants entering the intermittent stream.

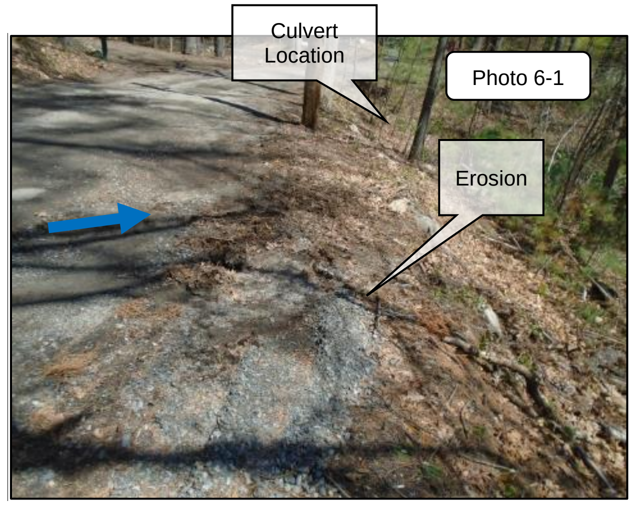
Proposed Improvements: Photo 6-3

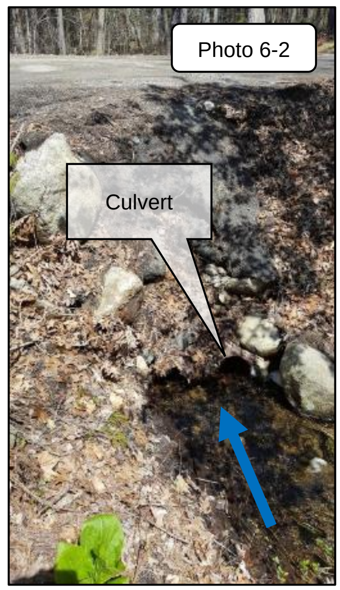
- Stabilize existing road shoulder with reinforced turf mat.
- Install a 100 linear foot vegetated buffer along the road shoulder, consisting of a double row of shrubs at approximately 3 foot spacing on center to slow runoff velocities, trap sediment, and thereby minimize migration of sediment and other pollutants into the channel.
- Install strategically located stone check dams to dissipate concentrated flow and minimize erosive energy.

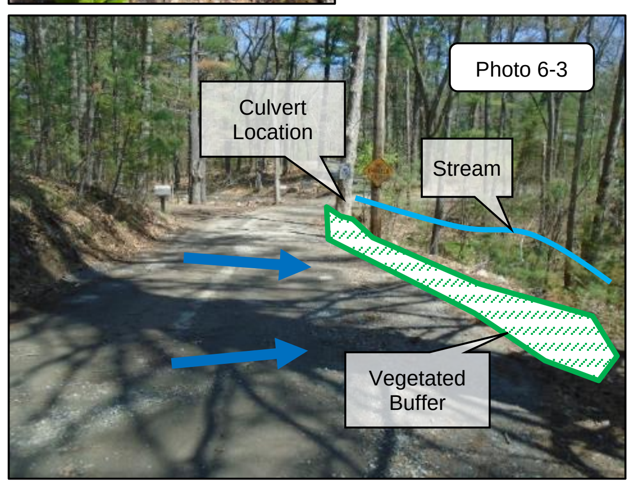
Expected O&M: Inspect plantings annually and replace as needed.

Wetland Permitting: As a project with minor buffer zone disturbances, WPA permitting is expected to require submittal of an ANOI.

Sizing Characteristics	
Drainage Area (acres)	0.23
Impervious Area (%)	22
Estimated Load Reduction (lb/yr)	
TN (lbs/yr)	0.26
TP (lbs/yr)	-
TSS (lbs/yr)	67.2
Estimated Costs ($)	
Total	$10,700







Site 7: Morningside Drive

Intersection with Clover Circle

Site Summary: Photos 7-1, 7-2, 7-3

Scour and accumulated sediment was observed along the southern side of Morningside Drive. The area drains to a catch basin with discharges to an intermittent stream that connects with Frye's Brook. A catch basin located across the street at the foot of Clover Circle receives runoff from the northwestern of Clover Circle (and possibly from Morningside Drive to the east), and discharges to the same intermittent stream.

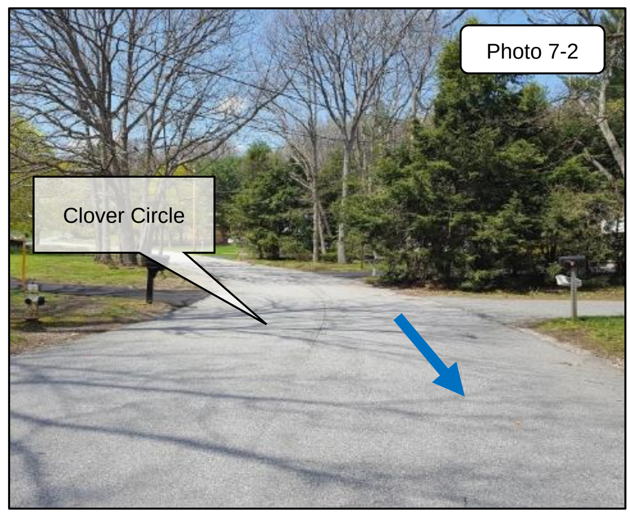
Proposed Improvements: Photos 7-1 and 7-3

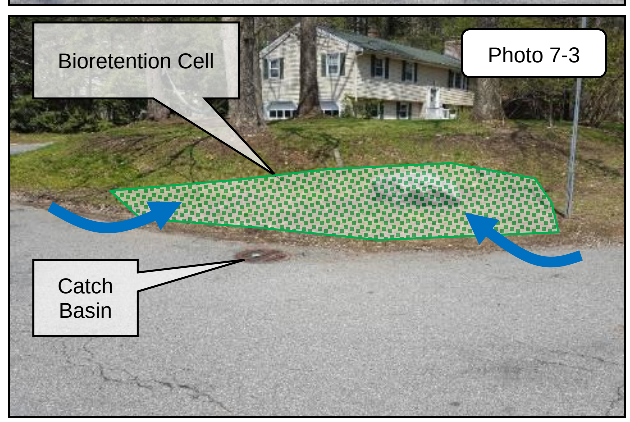
Install a 100-linear foot vegetated water quality swale with stone check dams to stabilize the Morningside Drive road shoulder and minimize erosion. Install 400 square foot bioretention cell at foot of Clover Circle. The existing catch basin would be used as an overflow during larger storm events.

Expected O&M: Remove accumulated sediment from bioretention cell and swale annually and maintain/replace plants as needed every two years.

Wetland Permitting: As a project with minor buffer zone disturbances, WPA permitting is expected to require submittal of an ANOI.

Sizing Characteristics	
Drainage Area (acres)	1.03
Impervious Area (%)	26
Estimated Load Reduction (lb/yr)	
TN (lbs/yr)	1.5
TP (lbs/yr)	0.17
TSS (lbs/yr)	105.8
Estimated Costs ($)	
Total	$18,191





According to Ms. Amy Janovsky who has observed previous wet-weather flow in this area, the bioretention cell might receive a larger proportion of discharge on the opposite site of Clover Circle.

Site 8: Frye's Brook Tributary Crossing

Rattlesnake Hill Road (West of Boston Road)

Site Summary: Photo 8-1

Evidence of previous scour and erosion into a tributary of Frye's Brook was observed adjacent to the headwall, just downstream of the culvert crossing under Rattlesnake Hill Road (Photo 8-1). The road shoulder was disturbed and provided a direct avenue for untreated runoff into the tributary.

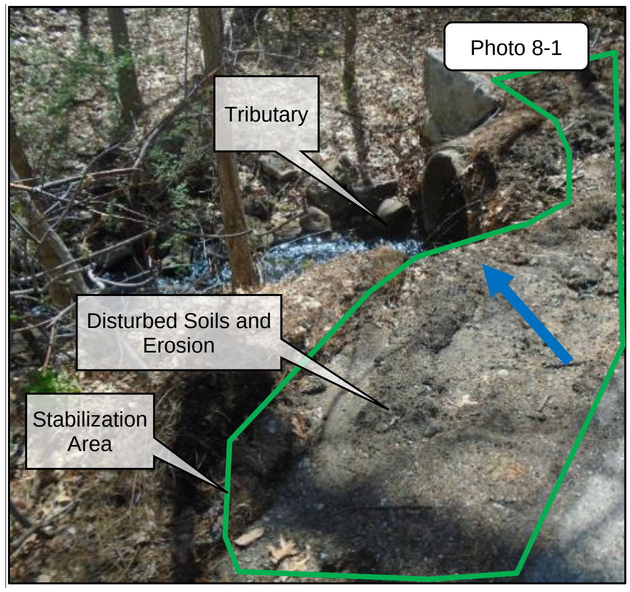
Proposed Improvements: Photo 8-1

Stabilize existing road shoulder with turf reinforcement mat and cover with riprap rock slow runoff velocities and minimize migration of sediment into the tributary.

Expected O&M: Inspect riprap for signs of deterioration. Remove accumulated sediment annually.

Wetland Permitting: As a project with minor buffer zone disturbances, WPA permitting is expected to require submittal of an ANOI.

Sizing Characteristics	
Drainage Area (acres)	0.96
Impervious Area (%)	30
Estimated Load Reduction (lb/yr)	
TN (lbs/yr)	-
TP (lbs/yr)	-
TSS (lbs/yr)	-
Estimated Costs ($)	
Total	$4,250



Site 9: Fern Road Median

Vicinity of Dug Pond

Site Summary: Photos 9-1, 9-2

The road median receives runoff from the northern portion of Fern Road and a long, steep driveway from 3 Fern Road. Evidence of past scour was observed along the median.

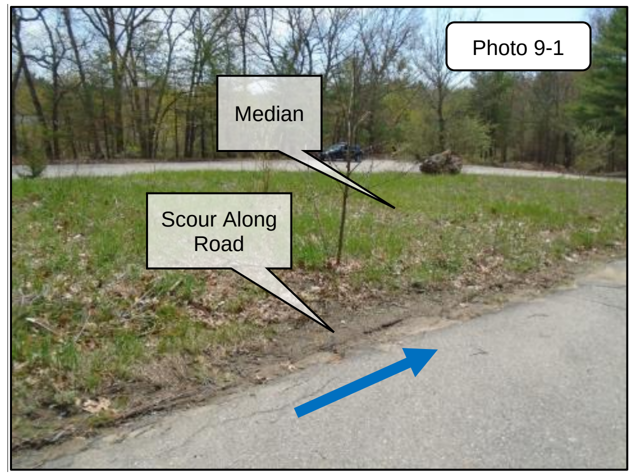
Proposed Improvements: Photo 9-3

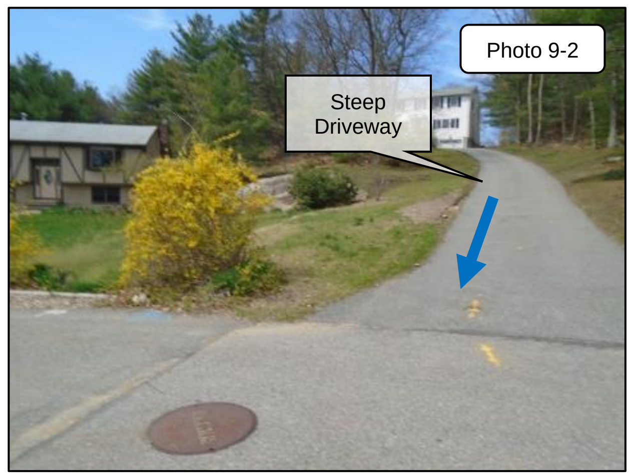
Install 500 square foot bioretention cell within the median. There is no stormwater infrastructure downstream of the median and overflow would sheet down Glenwood Avenue.

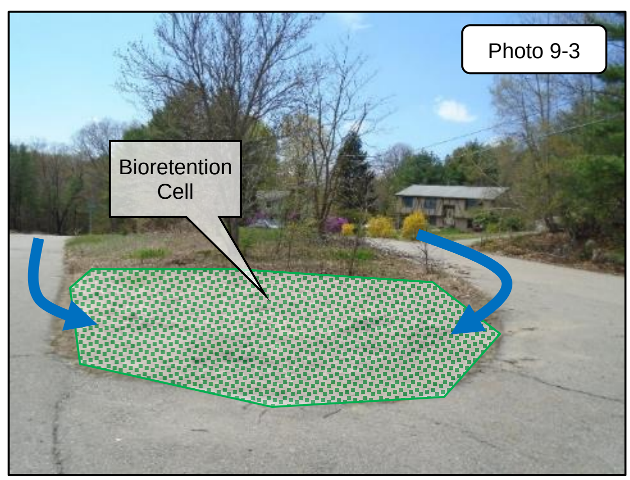
Expected O&M:

Remove accumulated sediment from bioretention cell annually and maintain/ replace plants as needed every two years.

Sizing Characteristics	
Drainage Area (acres)	0.97
Impervious Area (%)	26
Estimated Load Reduction (lb/yr)	
TN (lbs/yr)	2.2
TP (lbs/yr)	0.19
TSS (lbs/yr)	97.2
Estimated Costs ($)	
Total	$16,014







Site 10: Azalea Drive

End of Cul-de-sac

Site Summary: Photo 10-1

The road slopes to a median the end of the cul-de-sac. A catch basin is located downstream of the median, which discharges to Mill Reservoir through a 12-inch reinforced concrete outfall. The outfall is located on private property and was not visited during the site assessment.

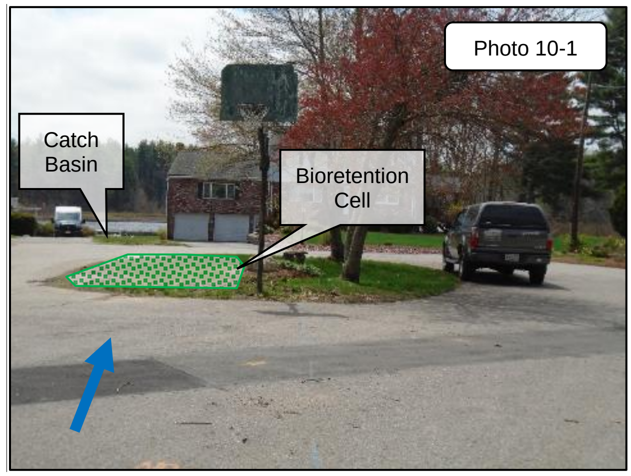
Proposed Improvements: Photo 10-1

- Install bioretention cell, approximately 300 square feet in size, within the median. The existing catch basin would be used as an overflow during larger storm events which exceed the storage capacity of the proposed bioretention cell.
- Locate the downstream outfall and inspect for signs of previous scour or erosion to determine if stabilization or outlet protection (e.g., energy dissipation) would be beneficial.

Expected O&M:

Remove accumulated sediment from bioretention cell annually and maintain/ replace plants as needed every two years.

Sizing Characteristics	
Drainage Area (acres)	0.38
Impervious Area (%)	53
Estimated Load Reduction (lb/yr)	
TN (lbs/yr)	1.89
TP (lbs/yr)	0.19
TSS (lbs/yr)	88.67
Estimated Costs ($)	
Total	$10,163



3. Secondary BMP Recommendations

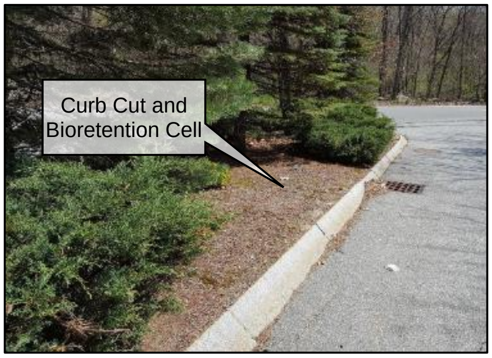
This section includes additional potential structural BMP locations as well as miscellaneous observations from the watershed assessment.

Location 11: Woburn Street in Vicinity of White Oak Drive

Evidence of erosion and past scour was observed along the road shoulder near White Oak Drive. According to White Oak Drive residents, drainage from this area sheets downstream to White Oak Drive where it ponds and collects sand before discharging to Foster's Pond.

Install gravel lined trench and level spreader to attenuate flows and minimize scour and evaluate further energy dissipation solutions at the intersection of White Oak Drive such as riprap or vegetative buffers.

Location 12: Ashwood Drive (Wilmington)



Multiple potential implementation locations were observed within the right of way in this subdivision. The road slopes to a catch basin at the foot of the road which discharges to an existing detention basin.

Cut existing curb and install bioretention cell within the median. Direct overflow to existing catch basin.

Location 13: Fiorenza Drive

Multiple potential implementation locations were observed within the right of way of this subdivision. The street is curbed with sidewalk on both sides.

Perform curb cut and install narrow water quality swales within the narrow median. Direct overflow to existing downstream catch basin.

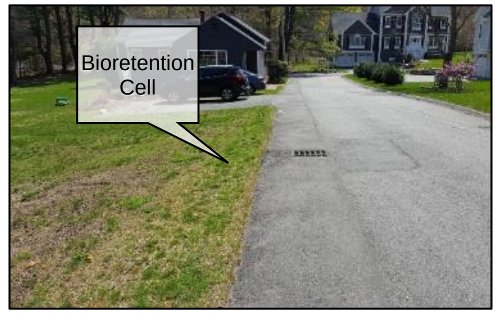
Location 14: Hawk Ridge Road

A catch basin at the end of the cul-de-sac receives runoff from a large upstream portion of the road. The catch basin discharges to an outfall located in the adjacent wetland.

Install bioretention cell around existing catch basin and energy dissipation outlet protection at existing outfall.

Location 15: Courtney Lane

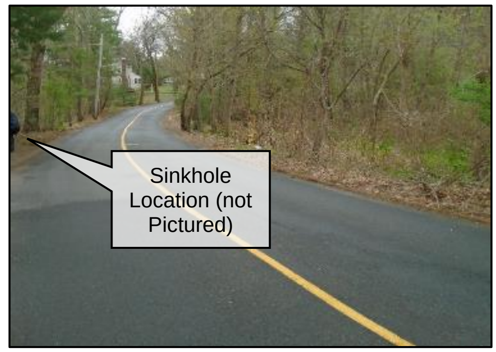
A catch basin receives runoff from the upstream portion of Courtney Lane. Install bioretention cell in right of way adjacent to catch basin.



Location 16: Frye's Brook Crossing County Road

The road was recently resurfaced and a small sink hole, approximately 2-4 inches in diameter, was observed on the northern shoulder. It left unrepaired, the sink hole might continue to increase size and could eventually become a public safety concern.

Repair sinkhole by refilling with well compacted and suitable subgrade material then apply patch to road surface.



Location 17: Meadowbrook Drive

Multiple potential implementation locations were observed within subdivisions in the upstream portion of the Watershed.

For example, install bioretention cell within right of way and configure to overflow to existing catch basin on Meadowbrook Drive.

Location 18: Chatham Road

A stone headwall was collapsing within the upper-most portion of the Frye's Brook tributary. The culvert was buried on the downstream side and the capacity appeared to be fully compromised. The collapsed culvert could potentially be a flood hazard.

Inspect and repair culvert and headwall.

Catch Basin Cleaning *(Town Activity)*

Catch basin cleaning is an infrastructure maintenance practice that can used to reduce pollutant discharge to receiving waters. Frequent clean-out can retain the volume in the catch basin sump available for capture of suspended sediments and treatment of stormwater flows. At a minimum, catch basins should be cleaned once or twice per year. Increasing the frequency of clean-out can improve the performance of catch basins, particularly in industrial or commercial areas.

A requirement of the 2016 Massachusetts Small MS4 General Permit (Page 49)[9], permitees are required to establish a schedule with a goal to routine cleaning such that no catch basin is more than 50 percent full at any time. Catch basin cleaning activities are to be reported in the Town's Storm Water Management Plan (SWMP).

By working with the Towns of Andover and Wilmington, a more frequent catch basin cleaning schedule could be implemented. Residents can contribute by clearing catch basin grates of debris and sediment after large storm events. To maintain sump capacity for proper catch basin performance, it is preferable to clean catch basins before they have accumulated sediment to half of capacity. If contracted out to a private firm, catch basin cleaning will typically cost an estimated average of $30 per catch basin.

The water quality benefits (i.e., pollutant reduction) of catch basin cleaning will vary considerably, depending on site-specific conditions such as land use, the size of the drainage area contributing to each basin, catch basin sump volume, extent of localized erosion, time elapsed since last cleaning, etc. The 2016 Massachusetts Small MS4 General Permit (Appendix F, Attachment 2)[10] provides a method for calculating phosphorus and nitrogen reduction credits for catch basin cleaning, as follows:

$$\text{Credit}_{CB} = IA_{CB} \times PLE_{IC\text{-land use}} \times PRF_{CB} \qquad \textbf{(Equation 2-2)}$$

Where:

Credit_{CB} = Amount of phosphorus load removed by catch basin cleaning (lb/year)

IA_{CB} = Impervious drainage area to catch basins (acres)

$PLE_{IC\text{-and use}}$ = Phosphorus Load Export Rate for impervious cover and specified land use (lb/acre/yr) (see Table 2-1)

PRF_{CB} = Phosphorus Reduction Factor for catch basin cleaning (see Table 2-4)

Table 2-4: Phosphorus reduction efficiency factor (PRF_{CB}) for semi-annual catch basin cleaning

Frequency	Practice	PRF_{CB}
Semi-annual	Catch Basin Cleaning	0.02

[9] https://www3.epa.gov/region1/npdes/stormwater/ma/2016fpd/final-2016-ma-sms4-gp.pdf

[10] https://www3.epa.gov/region1/npdes/stormwater/ma/2016fpd/appendix-f-2016-ma-sms4-gp.pdf

Outfall Evaluation *(Town Activity)*

Additionally, it appears that there are numerous outfalls (and their tributary areas including catchbasins) in Wilmington (particularly along Andover Street) and in Andover (at various locations) that have likely not recently been examined to evaluate their adequacy for reducing direct stormwater flows into Foster's Pond and its tributaries. The FPC will work with both towns to locate and examine outfalls and their catchment areas to evaluate whether improvements could reduce phosphorous loading to the Pond. Such an evaluation could be performed in parallel with the Illicit Discharge Detection and Elimination (IDDE) Program required by Section 2.3.4.7 of the 2016 Massachusetts Small MS4 General Permit which requires that outfalls be inventoried and ranked.

Enhanced Street / Pavement Cleaning Programs *(Town Activity)*

Street sweeping can be an effective practice to reduce watershed nutrient loading by providing cleanup and removal of solids, including organic debris (leaves, pine needles), sand, and fines that accumulate on roadways. Without street sweeping, these materials contribute nutrients and other pollutants such as salt to receiving waters, and increase the frequency of maintenance required to maintain performance of catch basins and other storm water infrastructure.

Enhanced municipal street sweeping is recommended, with a focus on increased frequency in the spring and summer months when buildup of organic materials on roads tends to be highest. The benefits of increased street sweeping will also be greatest in areas with highest tree canopy cover, as these areas produce the most leaves that can contribute nutrient to surface waters through decomposition. Specific target areas and sweeping frequencies should be established based on coordination with the Towns of Andover and Wilmington.

The 2016 Massachusetts Small MS4 General Permit (Appendix F, Attachment 2) provides a method for calculating phosphorus and nitrogen reduction credits for enhanced street sweeping, as follows:

$Credit_{sweeping} = IA_{swept} \times PLE_{IC\text{-}land\ use} \times PRF_{sweeping} \times AF$ **(Equation 2-1)**

Where:

$Credit_{sweeping}$ = Amount of phosphorus load removed by enhanced sweeping program (lb/year)

IA_{swept} = Area of impervious surface that is swept under the enhanced sweeping program (acres)

$PLE_{IC\text{-}land\ use}$ = Phosphorus Load Export Rate for impervious cover and specified land use (lb/acre/yr) (see Table 2-1)

$PRF_{sweeping}$ = Phosphorus Reduction Factor for sweeping based on sweeper type and frequency (see Table 2-3).

AF = Annual Frequency of sweeping. For example, if sweeping does not occur in Dec/Jan/Feb, the AF would be 9 mo./12 mo. = 0.75. For year-round sweeping, AF=1.0[1]

As an alternative, the permittee may apply a credible sweeping model of the Watershed and perform continuous simulations reflecting build-up and wash-off of phosphorus using long-term local rainfall data.

Table 2-3: Phosphorus reduction efficiency factors ($PRF_{sweeping}$) for sweeping impervious areas

Frequency[1]	Sweeper Technology	$PRF_{sweeping}$
2/year (spring and fall)[2]	Mechanical Broom	0.01
2/year (spring and fall)[2]	Vacuum Assisted	0.02
2/year (spring and fall)[2]	High-Efficiency Regenerative Air-Vacuum	0.02
Monthly	Mechanical Broom	0.03
Monthly	Vacuum Assisted	0.04
Monthly	High Efficiency Regenerative Air-Vacuum	0.08
Weekly	Mechanical Broom	0.05
Weekly	Vacuum Assisted	0.08
Weekly	High Efficiency Regenerative Air-Vacuum	0.10

Element D: Identify Technical and Financial Assistance Needed to Implement Plan

Element D: Estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.

Table D-1 presents the funding needed to implement the management measures presented in this watershed plan. The table includes costs for structural and non-structural BMPs and operation and maintenance materials. The table also includes anticipated performance of BMPs where applicable and other characteristics (e.g., drainage area).

Note that costing of additional recommendations for Public Education and Outreach (Element E) and monitoring (Elements H&I) are not included in the below table as it is anticipated that those elements will be performed by volunteers on an on-kind basis.

Table D-1: Summary of Funding Needed to Implement the Watershed Plan

ID	BMP Description	Management Measures	Drainage Area (ac)	Impervious Area (%)	Est. Load Reduction (lb/yr)			Cost Estimates ($)			
					TN	TP	TSS	Capital	Annual O&M	Technical Assistance	Total
Structural and Non-Structural BMPs (from Element C)											
1	Foster's Pond Road (Intersection with Pomeroy Road)	Two (2), 200-sq. ft. bioretention cells	0.69	59%	2.9	0.3	138	$ 8,009	$ 250	$ 3,204	$ 11,463
2	Foster's Pond Road (Adjacent to #12)	500-sq. ft. bioretention cell; outlet protection (if needed)	0.96	19%	1.7	0.2	76	$ 11,144	$ 250	$ 4,458	$ 15,852
3	Foster's Pond Road (Adjacent to #26)	Two (2) hydrodynamic separators	0.87	29%	-	-	32	$ 14,000	$ 200	$ 5,600	$ 19,800
4	End of Pomeroy Road	1,500 sq. ft. constructed wetland with level spreader and sediment forebay; outlet protection (if needed)	4..25	15%	7.0	0.6	320	$ 51,067	$ 400	$ 20,427	$ 71,894
5	Snowberry Road (end of cul-de-sac)	200-sq. ft bioretetion cell; outlet protection with level spreader	2.75	27%	1.7	0.2	76	$ 8,590	$ 250	$ 3,436	$ 12,276
6	Willard Circle (upstream of intermittent stream crossing)	100-ft. vegetated buffer with stone check dams	0.23	22%	26.0	-	67	$ 7,500	$ 200	$ 3,000	$ 10,700
7	Morningside Drive (at Clover Circle)	100-ft vegetated water quality swale; 400-sq. ft. bioretention cell	1.03	26%	1.5	0.2	106	$ 12,779	$ 300	$ 5,112	$ 18,191
8	Frye Brook (at Rattlesnake Road)	Stabilize road shoulder	0.96	30%	-	-	-	$ 3,000	$ 50	$ 1,200	$ 4,250
9	Fern Road Median	500 sq.-ft. bioretention cell	0.97	26%	2.2	0.2	97	$ 11,260	$ 250	$ 4,504	$ 16,014
10	Azalea Drive (end of cul-de-sac)	300 sq. ft. bioretention cell; outlet protection (if needed)	0.38	53%	1.9	0.2	89	$ 7,081	$ 250	$ 2,832	$ 10,163
11 to 18	See WBP for identification of secondary measures	See WBP for details	-	-	-	-	-	$ -	$ -	$ -	$ -
-	Catch Basin Cleaning, Street Sweeping, and Outfall Evaluation (Town Activity)	See WBP for details	-	-	-	-	-	$ -	$ -	$ -	$ -
							TOTALS:	**$134,430**	**$ 2,400**	**$ 53,772**	**$ 190,602**

Notes

Capital costs obtained from WBP Element C

Operation and maintenance cost estimates obtained from past projects. Actual costs may vary widely depending on who performs maintenance (e.g., Town, residents, other)

Technical assistance (i.e. engineering) estimated based on capital costs - design (30%), survey (2%), permitting (3%), Construction Quality Assurance (5%)

Element E: Public Information and Education

Element E: An information/education (I/E) component of the watershed plan used to:

1. Enhance public understanding of the project; and
2. Encourage early and continued public participation in selecting, designing, and implementing the NPS management measures that will be implemented.

Step 1: Goals and Objectives

The goals and objectives for the watershed information and education program.

1. Provide information about specific stormwater improvements that are being implemented and their water quality benefits.
2. Provide information to promote watershed stewardship.

Step 2: Target Audience

Target audiences that need to be reached to meet the goals and objectives identified above.

1. All watershed residents.
2. Recreational users of Foster’s Pond (boaters, fishermen, etc.).

Step 3: Outreach Products and Distribution

The following outreach products are anticipated:

1. Periodically update website highlighting anticipated improvements and updates.
2. Develop brochure promoting watershed stewardship, post to website (as described in more detail below).
3. Implement a raingarden demonstration program and green infrastructure workshop (as described in more detail below).
4. Phosphorous fertilizer reduction program (as described in more detail below).

Step 4: Evaluate Information/Education Program

The effectiveness of the program is anticipated to be evaluated in the following ways:

1. Track number of web page views (goal of 500 views per year).
2. Track how many neighborhoods attend green infrastructure workshop and implement raingardens (goal of 1 neighborhood and 5 total raingardens initially).

Raingarden Program

Locations with Fast Infiltrating Soils

An initial raingarden program could be implemented to educate watershed residents about Low Impact Development (LID) stormwater management practices and to promote this approach throughout the Watershed.

Foster's Pond is fortunate to be surrounded by areas with soils that are generally favorable for implementation of raingardens and other infiltration practices recommended in this report (see attached soils map, Figure C-2). Soils classified in hydrologic soils groups A and B have rates of infiltration conducive to practices such as raingardens. However, proper design can allow raingardens to function well in areas with less favorable native soils. As such, the raingarden program could be used to promote raingardens at numerous locations throughout the Foster's Pond watershed.

Given the favorable soil types surrounding the Pond, we recommend that a raingarden program initially be implemented on roads with direct stormwater drainage to Foster's Pond:

- Foster's Pond Road
- Pomeroy Road
- Snowberry Road
- Azalea Drive
- Morningside Drive

Raingardens can vary in size depending on drainage area and property owner preference, and typically range between 50 to 200 square feet. These raingardens would help improve water quality and provide pretreatment for stormwater that would otherwise runoff directly into the Pond and its tributaries. For the load reduction estimates below, five (5) 100-square foot raingardens were assumed as part of an initial raingarden program.

For sites recommended for BMP projects where funding is not available to implement the proposed improvements, raingardens should be considered as lower-cost alternatives which, while not as effective, could nevertheless contribute to significant phosphorous reduction.

Estimated Phosphorus Reduction: 0.16 – 0.49 lb. P/yr

Typical rain garden installation along road shoulder (Silver Lake watershed, Wilmington, MA)

Lakeside rain garden providing storage during a rain storm (Lake Shirley, Lunenburg, MA).

Newly planted rain garden with shrub planting scheme (Mirror Lake watershed, Tuftonboro, NH).

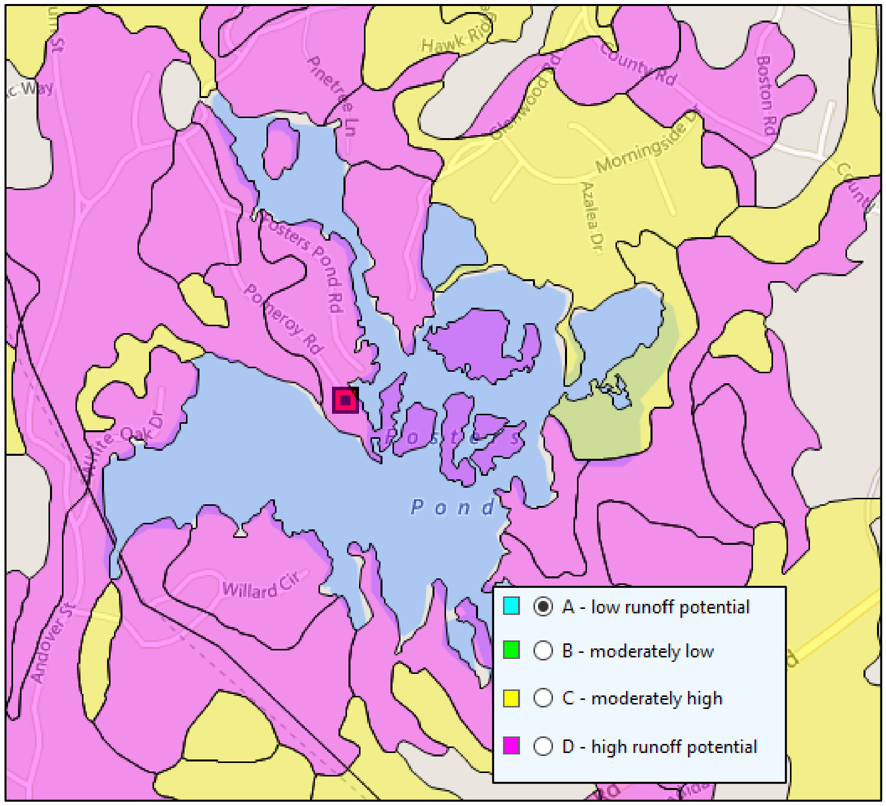


Figure C-2. Foster's Pond Hydrologic Soil Classifications
(Image Courtesy of EPA National Stormwater Calculator)

Fertilizer Phosphorus Reduction Program

All Locations within Watershed

Landscaping fertilizers can be a significant source of phosphorus from areas of residential development and other areas where grass lawns are maintained (e.g. office parks, schools, sports fields, etc.).

Massachusetts in 2012 enacted legislation aimed at reducing the use of fertilizers containing phosphorous, including the use of such fertilizers on residential lawns. (See M.G.L. c.128 , §§2(k) and 65A.) Implementing regulations adopted by the Department of Agricultural Resources (31 C.M.R. 31:00) require, among other things, that retailers post a sign with the following language if they sell fertilizers containing phosphorous:

> "Phosphorus runoff poses a threat to water quality. Therefore, under Massachusetts law, phosphorus containing fertilizer may only be applied to lawn or non-agricultural turf when (i) a soil test indicates that additional phosphorus is needed for the growth of that lawn or non-agricultural turf; or (ii) is used for newly established lawn or non-agricultural turf during the first growing season."

Prohibitions on the use of lawn fertilizers containing phosphorous, with certain exceptions, apply to homeowners, commercial lawn companies, and other users.

While the new law has undoubtedly cut back on the use of phosphorous in fertilizers, such fertilizers continue to be sold at retail and some retailers do not display the required signage. The extent to which homeowners are aware of the law is unclear and some homeowners may continue to believe erroneously that phosphorous in fertilizers in needed for a healthy lawn.

Accordingly, it may be productive for the Foster's Pond Corporation, working with the Towns of Andover and Wilmington, to develop a program to reduce pollution from fertilizer applications within the Watershed. This program could include some or all of the following elements:

- **Educate homeowners, businesses, and appropriate Town departments** about the phosphorus-free fertilizer law and its role in protecting water quality. Appropriate materials could be developed for the FPC and Town websites. Public outreach materials (e.g., brochure, flyer) are also recommended to ensure that watershed residents are informed of the program, including a discussion of the benefits of and options for "no-fertilizer" landscaping.

- **Educate retailers** about the phosphorus-free fertilizer law and its role in protecting water quality. The FPC could prepare and provide to retailers signage that complies with the retailers' legal obligation.

- **Work with the Towns to survey homeowners** on their use and knowledge of phosphorous-free fertilizers. A follow up survey is recommended to evaluate the performance of the program.

Estimated Phosphorus Reduction: The phosphorus load reductions that can be achieved by a fertilizer reduction program will vary depending on how the program is structured and implemented, as well as the extent to which homeowners and other users are already complying with the new law. For purposes of developing a load reduction estimate for this report, we have assumed that the program would be targeted to the 400 residential homes located in closest proximity to Foster's Pond, and that 15% of these homes (60 homes) fertilize a 2,000 square foot lawn area twice per growing season using 10-10-10 (N-P-K) formula fertilizer at a typical application rate of 3.5 lbs per 1000 square feet. If 25% to 50% of the homes using fertilizer are convinced to switch to phosphorus-free fertilizer, the amount of phosphorus applied to lawns within pond watersheds would be reduced by approximately 70 to 140 lbs. per year. If 10% of the applied fertilizer phosphorus washes into the pond via storm water runoff, then the estimated annual phosphorus load reduction would range from 7 to 14 lbs. P/year.

Additional Information for Recommended Outreach Activities

Public information and education efforts can be used to enhance public understanding of pond and watershed management issues for the Watershed, such as control/prevention of non-native species and phosphorus loading reduction projects. Public information and education about pond management efforts can be provided via Town and/or lake association websites, social media, print brochures, local newspaper articles, and other media.

Brochure: An educational print or web-based brochure could be developed on homeowner practices that reduce loading of phosphorus and other pollutants to the ponds. Example text is provided on the following page.

Public Education Workshops: There are many organizations that provide green infrastructure workshops focused towards educating property owners in the watershed on how to implement green infrastructure on their properties such as raingardens, rain barrels, infiltration trenches, vegetated buffers, low- or no-phosphorus fertilizers, etc. Specific topics typically addressed include:

- Stormwater and Green Infrastructure concepts
- Case study of benefits and costs
- Practices (including step-by step instruction on how to design and build a residential raingarden[11])
- Recommended native plantings
- Tools for estimating cost and pollutant load reductions
- Construction Do's and Don'ts

Other Resources: Homeowners within the Watershed are encouraged to review the following educational resources:

- **Massachusetts Nonpoint Source Pollution Management Manual:** http://projects.geosyntec.com/NPSManual/
- **Innovative Land Planning Techniques – A Handbook for Sustainable Development:** http://des.nh.gov/organization/divisions/water/wmb/repp/innovative_land_use.htm
- **The Vermont Raingarden Manual:** http://nsgl.gso.uri.edu/lcsg/lcsgh09001.pdf
- **A Shoreland Homeowner's Guide to Stormwater Management** http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/nhdes-wd-10-8.pdf

[11] Example step-by-step instructions prepared by Charles River Watershed Association

Example homeowner pollution prevention brochure text. Other content could include pond/watershed maps, information on aquatic plants and invasive species, and ongoing monitoring efforts.

How YOU Can Help Protect Foster's Pond!

"Just say No" to fertilizer. Lawn fertilizer is transported to Foster's Pond by storm water runoff, fueling algae blooms that reduce water clarity and can lead to beach closures. Use natural alternatives to lawn and garden chemicals and establish low-maintenance, native vegetation on your property.

Build a raingarden to manage stormwater runoff from your property. Raingardens protect water quality while beautifying your home and neighborhood! For more information, see: http://nsgl.gso.uri.edu/lcsg/lcsgh09001.pdf

Rain barrels are a great way to re-use rainwater from roofs for gardening and landscaping. A rain barrel will save most homeowners about 1,300 gallons of water during the peak summer months. Diverting this water from storm drains also decreases the impact of runoff to streams. Rain barrels can be purchased at many home and garden centers.

Keep **litter, leaves, and debris** out of street gutters and storm drains. Dispose of used oil, antifreeze, paints, and other household chemicals properly. Do not dump these products in storm drains. These outlets drain directly to Foster's Pond, contributing streams and wetlands.

Don't feed waterfowl! Bread and snack food are harmful to waterfowl Feeding discourages winter migration and encourages large bird flocks that degrade pond the shorelines with droppings and can contribute to beach closures.

Pick up after your pet! Use biodegradable doggie bags to collect pet waste. Don't dispose of pet waste in storm drains.

Control soil erosion on your property by planting ground cover and stabilizing erosion-prone areas.

Elements F & G: Implementation Schedule and Measurable Milestones

Element F: Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.

Element G: A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.

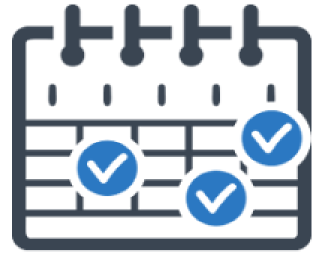


Table FG-1 provides a preliminary schedule for implementation of recommendations provided by this monitoring plan. It is expected that the WBP will be re-evaluated and updated in 2019 as needed based on ongoing monitoring results and other ongoing efforts.

Table FG-1: Implementation Schedule and Interim Measurable Milestones

Category	Action	Year(s)
Monitoring	Perform annual water quality sampling.	Annual
	Perform aquatic vegetation monitoring (per existing program).	Annual
Vegetation Control	Perform vegetation control per existing program.	Annual
Structural BMPs	Determine if applying for s.319 DEP Grant Funding is an option. If yes, apply for grant (applications expected to be due Spring 2018).	2018
	Implement 4 to 5 recommended structural BMPs with grant funding.	2019-2020
	Assess potential to implement additional recommended structural BMPs.	2021
Public Education and Outreach	Develop Public Education Brochure.	2017
	Initiate and Implement Fertilizer Phosphorus Reduction Program	2018
	Perform Green Infrastructure Workshop and initiate Raingarden Demonstration Program.	2018
	Construct raingardens using knowledge from workshop.	2019
Adaptive Management and Plan Updates	Re-evaluate Watershed Based Plan and adjust as needed based on ongoing efforts (e.g., based on monitoring results, 319 funding, etc.).	Bi-annual (next update - 2019)

Elements H & I: Progress Evaluation Criteria and Monitoring

ELEMENT H: A set of criteria used to determine (1) if loading reductions are being achieved over time and (2) if progress is being made toward attaining water quality goals. Element H asks ***"how will you know if you are making progress towards water quality goals?"*** The criteria established to track progress can be direct measurements (e.g., *E. coli* bacteria concentrations) or indirect indicators of load reduction (e.g., number of beach closings related to bacteria).

ELEMENT I: A monitoring component to evaluate the effectiveness of implementation efforts over time, as measured against the Element H criteria. Element I asks "***how, when, and where will you conduct monitoring?***"

The water quality target concentration(s) is presented under Element A of this plan. To achieve this target concentration, the annual loading must be reduced to the amount described in Element B. Element C of this plan describes the various management measures that will be implemented to achieve this targeted load reduction. The evaluation criteria and monitoring program described below will be used to measure the effectiveness of the proposed management measures (described in Element C) in improving the water quality of Foster's Pond.

Indirect Indicators of Load Reduction

Algae and Vegetation Monitoring: As previously discussed, Foster's Pond Corporation manages nuisance algae and vegetation on an as-needed basis and performs annual monitoring to track progress. Annual monitoring will be continued and used as a metric for understanding water quality trends in response to implementation of measures recommended as part of this WBP.

Project-Specific Indicators

Number of BMPs Installed: Element C of this WBP recommends the installation of BMPs at ten (10) different locations. The anticipated pollutant load reduction has been documented for each proposed BMP where applicable. The number of BMPs that were installed will be tracked and quantified as part of this monitoring program. If all recommended BMPs are installed, the anticipated phosphorus load reduction is estimated to be 1.5 pound per year.

Raingarden Workshop: The number of raingardens installed as part of the raingarden workshop can also be tracked and used to estimate pollutant load reductions. Phosphorus load reductions will vary significantly amongst raingardens. A 100-square foot raingarden can reasonably be expected to reduce phosphorus loading by approximately 0.1 pound per year.

Direct Measurements

In-Lake Phosphorus Monitoring: FPC will continue monitoring in-lake phosphorus concentrations through the annual monitoring program. In-lake phosphorus measurements will provide the most direct means of evaluating the effects of measures which have been implemented specifically to reduce phosphorus loading.

As discussed in Element A, the in-lake phosphorus concentrations predicted by the Vollenweider equation assume that the pond is uniformly mixed. As such, the results of the epilimnetic phosphorus monitoring during the summer (when the lake is stratified) are likely to understate the phosphorus levels that would be measured if the lake was uniformly mixed. However, regular monitoring of phosphorus levels from a profile (samples from the epilimnion, metalimnion and hypolimnion) at the five (5) monitoring locations (as shown on Figure HI-1) is recommended to provide data on phosphorus concentration trends in response to implementation of the measures described in Element C. Depending on available funding and volunteer resources, the following options for monitoring are recommended:

Note that a new monitoring location is proposed at the inlet of Frye's Brook within the Mill Reservoir.

Option 1: At minimum, continue baseline phosphorus sampling three times per year, during spring (late April/early May), mid-summer (early to mid-July) and late summer (early- to mid-September). At each of the four in-lake locations, collect samples from the surface, middle of the water column, and near the bottom (approximately 0.5m from bottom) using a Kemmerer sampler or similar type of depth sampling equipment. Also collect a surface grab sample from the inlet of Frye's Brook, just upstream of its confluence with Foster's Pond.

Kemmerer depth sampler

Option 2: In addition to the phosphorus monitoring described above, conduct the following during each of the three recommended sampling events:

- Collect chlorophyll-*a* samples (surface grab sample) at each in-lake location. Chlorophyll-a provides an indirect measure of algal productivity;
- Use a secchi disk to measure water clarirty;
- Use an *in-situ* multi-parameter water quality probe (e.g., YSI or comparable brand, which can be rented on a daily basis) to collect the following information at 0.5 meter intervals at each sampling location:
  - Temperature
  - Dissolved oxygen
  - Specific conductance
  - pH

Option 3: As a one-time effort to characterize seasonal internal phosphorus loading, the following could be conducted at the deep spot location of the main pond:

- Conduct phosphorus water column sampling and in-situ monitoring as described above, once every two weeks from ice-off until fall turnover (typically in mid-October, when the pond surface temperature becomes equal to the bottom temperature). The information gathered from this sampling program can be used to quantify the mass of phosphorus released seasonally from the pond's sediments, which occurs during summer thermal stratification when the hypolimnion becomes nearly depleted of oxygen.

Model Calibration and Future Use: Results from monitoring data can be used to calibrate and validate the trophic response model and adjust inputs accordingly (e.g., land use based component from Frye's Brook). Inputs to the model can be adjusted to predict changes in in-lake phosphorus concentrations based on recommended management actions (e.g., separation of septic systems, etc.) as described in Element A, Section 7 of this WBP.

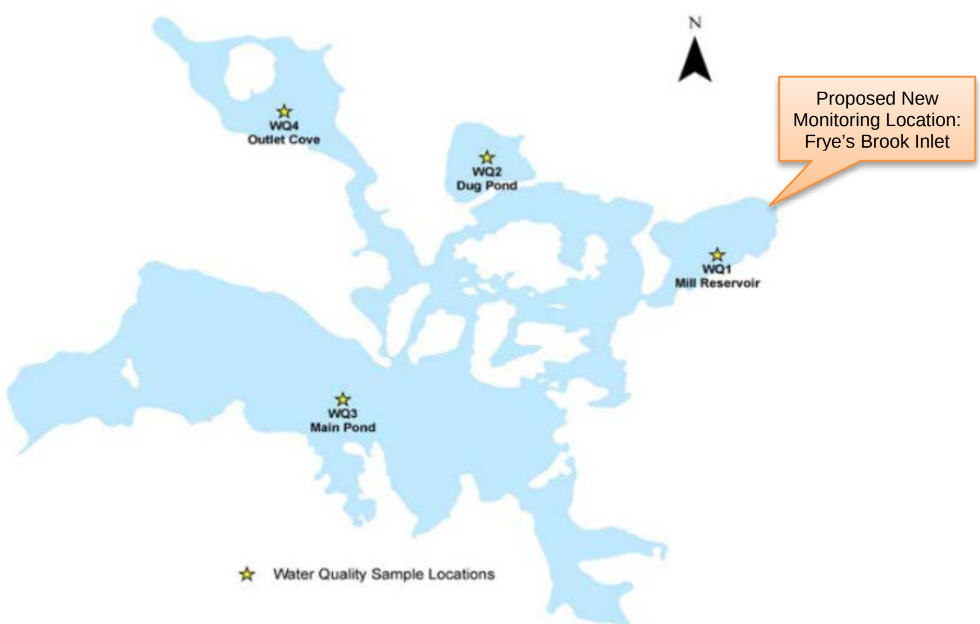


Figure HI-1. Proposed In-Lake Phosphorus Monitoring Locations
(Figure adapted from 2016 Solitude Year End Report)

Adaptive Management

If after 3 years of management measure implementation, interim targets are not met and the direct measurements and indirect indicators do not show improvement in the total phosphorus concentrations measured within Foster's Pond, the management measures and loading reduction analysis (Elements A through D) will be revisited and modified accordingly.

Summary and Recommendations

The Vollenweider equation (i.e. trophic response model) presented in Element A predicts an in-lake phosphorus concentration of 19.3 µg/L when Foster's Pond is in a fully mixed state. This predicted concentration would classify Foster's Pond as an upper-mesotrophic pond with regard to biological productivity, and is below the 25 µg/L threshold (lower limit) concentration for classification as a eutrophic pond. However, water quality sampling data indicates that measured phosphorus concentrations frequently exceed 25 µg/L during summer months (e.g., August) when the main pond basin is thermally stratified. In stratified ponds, peak phosphorus concentrations typically occur during late summer/early fall due to seasonal release of phosphorus from sediments. This seasonal phosphorus release, also known as "internal phosphorus loading", can contribute to nuisance algal blooms and associated decreased water clarity.

To achieve the long-term goals of protecting the water quality of Foster's Pond and reducing impairments associated with nutrient loading, a variety of watershed management best management practices (BMPs) are recommended. These recommendations include a combination of structural and non-structural BMPs, public education and outreach, and continued monitoring as summarized below.

Structural and Non-Structural BMPs

Structural stormwater management BMPs recommended in Element C of this report are typically capital intensive and are recommended to be implemented over time based on available resources. As previously discussed, typical funding mechanisms include state and federal grants such as the Section 319 Nonpoint Source Pollution Grant Program administered by MassDEP. Grants often require matching contributions in the form of cash or in-kind labor. For example, the Section 319 grant program requires a 40% non-federal match[12]. One potential avenue to fund the recommended BMPs in this report is to partner with the Town of Andover and the Town of Wilmington.

As presented in Element C, recommended non-structural BMPs include enhanced catch basin cleaning, street sweeping, and outfall evaluations. These programs could be implemented by the Towns of Andover and Wilmington and would protect Foster's Pond from pollutant loading while helping the Towns meet NPDES MS4 permit requirements by achieving phosphorus reduction credits.

Public Education and Outreach

Additional recommendations provided in Element E of this report are summarized below:

1. Prepare and post a brochure to the FPC website promoting watershed stewardship including reduction and elimination of phosphorus based fertilizers.
2. Initiate a Raingarden Program by holding a Green Infrastructure for Homeowners Workshop at FPC's next annual meeting and encourage homeowners to implement and build raingardens and other practices. A widely distributed approach where homeowners implement raingardens and other infiltrating practices at known problem areas (e.g. road shoulders where runoff sheets into the pond) is recommended as part of a long-term strategy to reduce nutrient loading to Foster's Pond.
3. Work with the Towns of Andover and Wilmington to initiate and implement and phosphorus and fertilizer reduction program.

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[12] A comprehensive summary of potential funding programs can be found at: http://prj.geosyntec.com/prjMADEPWBP_Files/Guide/Element%20D%20-%20Funds%20and%20Resources%20Guide.pdf.

Monitoring and Modeling

Finally, three tiered options for continued water quality monitoring are provided by Element I of this report. It is recommended that monitoring be performed based on available resources and funding. Data from the ongoing monitoring program can be used to calibrate and validate the trophic response model.

References / Appendix

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MassDEP Water Quality Assessment Reports

"*Shawsheen River Watershed 2000 Water Quality Assessment Report*"

Appendix A – Pollutant Load Export Rates (PLERs)

Land Use & Cover[1]	PLERs (lb/acre/year)		
	(TP)	(TSS)	(TN)
AGRICULTURE, HSG A	0.45	7.14	2.59
AGRICULTURE, HSG B	0.45	29.4	2.59
AGRICULTURE, HSG C	0.45	59.8	2.59
AGRICULTURE, HSG D	0.45	91.0	2.59
AGRICULTURE, IMPERVIOUS	1.52	650	11.3
COMMERCIAL, HSG A	0.03	7.14	0.27
COMMERCIAL, HSG B	0.12	29.4	1.16
COMMERCIAL, HSG C	0.21	59.8	2.41
COMMERCIAL, HSG D	0.37	91.0	3.66
COMMERCIAL, IMPERVIOUS	1.78	377	15.1
FOREST, HSG A	0.12	7.14	0.54
FOREST, HSG B	0.12	29.4	0.54
FOREST, HSG C	0.12	59.8	0.54
FOREST, HSG D	0.12	91.0	0.54
FOREST, HSG IMPERVIOUS	1.52	650	11.3
HIGH DENSITY RESIDENTIAL, HSG A	0.03	7.14	0.27
HIGH DENSITY RESIDENTIAL, HSG B	0.12	29.4	1.16
HIGH DENSITY RESIDENTIAL, HSG C	0.21	59.8	2.41
HIGH DENSITY RESIDENTIAL, HSG D	0.37	91.0	3.66
HIGH DENSITY RESIDENTIAL, IMPERVIOUS	2.32	439	14.1
HIGHWAY, HSG A	0.03	7.14	0.27
HIGHWAY, HSG B	0.12	29.4	1.16
HIGHWAY, HSG C	0.21	59.8	2.41
HIGHWAY, HSG D	0.37	91.0	3.66
HIGHWAY, IMPERVIOUS	1.34	1,480	10.2
INDUSTRIAL, HSG A	0.03	7.14	0.27
INDUSTRIAL, HSG B	0.12	29.4	1.16

INDUSTRIAL, HSG C	0.21	59.8	2.41
INDUSTRIAL, HSG D	0.37	91.0	3.66
INDUSTRIAL, IMPERVIOUS	1.78	377	15.1
LOW DENSITY RESIDENTIAL, HSG A	0.03	7.14	0.27
LOW DENSITY RESIDENTIAL, HSG B	0.12	29.4	1.16
LOW DENSITY RESIDENTIAL, HSG C	0.21	59.8	2.41
LOW DENSITY RESIDENTIAL, HSG D	0.37	91.0	3.66
LOW DENSITY RESIDENTIAL, IMPERVIOUS	1.52	439	14.1
MEDIUM DENSITY RESIDENTIAL, HSG A	0.03	7.14	0.27
MEDIUM DENSITY RESIDENTIAL, HSG B	0.12	29.4	1.16
MEDIUM DENSITY RESIDENTIAL, HSG C	0.21	59.8	2.41
MEDIUM DENSITY RESIDENTIAL, HSG D	0.37	91.0	3.66
MEDIUM DENSITY RESIDENTIAL, IMPERVIOUS	1.96	439	14.1
OPEN LAND, HSG A	0.12	7.14	0.27
OPEN LAND, HSG B	0.12	29.4	1.16
OPEN LAND, HSG C	0.12	59.8	2.41
OPEN LAND, HSG D	0.12	91.0	3.66
OPEN LAND, IMPERVIOUS	1.52	650	11.3
[1]HSG = Hydrologic Soil Group			