Hopedale Pond Green Infrastructure Design (Site C1)

Hopedale, Massachusetts

PREPARED FOR:
Park Commission
Town of Hopedale
78 Hopedale Street
Hopedale, MA

PREPARED BY:
ESS Group, Inc.
10 Hemingway Drive, 2nd Floor
East Providence, Rhode Island 02915

ESS Project No. H172-001

Revised: April 2016

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This project was funded by an agreement awarded by the Environmental Protection Agency to the New England Interstate Water Pollution Control Commission in partnership with the Narragansett Bay Estuary Program. Although the information in this document has been funded wholly or in part by the United States Environmental Protection Agency under agreements CE96184201 and CE96172201 to NEIWPCC, it has not undergone the views of the Agency and no official endorsement should be inferred. The viewpoints expressed here do not necessarily represent those of the Narragansett Bay Estuary Program, NEIWPCC, or EPA, not does mention of trade names, commercial products, or causes constitute endorsement or recommendation of use.

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Prepared By:

M. James Riordan, AICP, LEED AP
Principal Scientist

1.0 PURPOSE AND BACKGROUND

The purpose of the study described in this report is to continue development of the management strategy and begin the process of reopening Hopedale Pond to direct-contact recreation. Specifically, this study focuses on advancing best management practice (BMP) designs from conceptual level[1] to budget level (i.e., approximately 50% completion)[2] for the BMP proposed in Hopedale Park near the intersection of Freedom Street and Dutcher Street. Conceptual designs proposed a subsurface infiltration system; however, infiltration was determined to be infeasible due to high groundwater found during the soil evaluation of the site. Grassed bioretention with a liner is proposed in place of subsurface infiltration. Bioretention will provide excellent pollution treatment capacity, but will not infiltrate water. This project is being completed through a Southern New England Program grant provided by the Narragansett Bay Estuary Program and the New England Interstate Water Pollution Control Commission.

Hopedale Beach has been out of active use for several years and does not currently support swimming due high levels of pathogens. The primary source of bacteria to Hopedale Pond was identified as part of the Diagnostic and Feasibility Study for Hopedale Pond (ESS, 2009) as the Dutcher Street Outfall, which was found to contribute up to 200,000 cfu/100 ml and phosphorus in the range of 0.2 – 0.3 mg/L, in part from wet weather. These levels of pollutants were confirmed in a 2014 sampling study. The Dutcher Street Outfall is the largest outfall to Hopedale Pond and drains approximately 95 acres of developed land.

The Town of Hopedale (Town) Parks Commission is spearheading an effort to improve water quality and reestablish direct-contact recreation (e.g., swimming) using green infrastructure retrofits, pet waste management, and waterfowl management. Town’s project strategy in this study is to conceptually design work and install stormwater infiltration in Hopedale Town Park, bioretention in the Town-owned area across from the park on the other side of Dutcher Street, and replant vegetation on the Town Beach for the purpose of waterfowl deterrence. The Town is also pursuing water quality management actions. Follow-on steps may include completion and implementation of stormwater design work at three or more locations, implementation waterfowl management, illicit discharge identification and elimination, public education and outreach, and coordination with the Town of Milford, which is partially within the Dutcher Street Outfall catchment area.

2.0 DESCRIPTION OF HOPEDALE POND AND CURRENT CONDITIONS

Hopedale Pond (MA51065) in Hopedale, Massachusetts is a warm-water impounded area of the Mill River. The Mill River is a tributary to the Blackstone River. The Hopedale Pond and the Mill River originally provided power to the former Draper Corporation at Draper Mill. South of the Hopedale Pond, Mill River flows under the old Draper Mill building and then down to Route 16 in Hopedale.

Hopedale Pond is a priority habitat for the Nature Heritage and Endangered Species Program. Fish populations reportedly include yellow perch, bluegills, pumpkinseeds, golden shiners, chain pickerel, yellow bullheads, largemouth bass, black crappie, brown bullheads and American eel. White catfish are also known to be present.[3] The American Brook Lamprey, which is a threatened species in Massachusetts, inhabits the Mill River including Hopedale Pond. Mitigation of stormwater discharged to Hopedale Pond is noted as important to sustain the lamprey and other fish populations in the pond (Town of Hopedale, 2004).

[1] Conceptual designs for several locations near Hopedale Park were previously completed and provided in the report entitled, *Hopedale Pond Storm Drain Mapping, Conceptual Stormwater Designs and Sampling* (ESS 2015).

[2] Design work for this study was conducted using LiDAR data and relative elevation data collected during drainage system mapping. In some cases elevation data was interpolated based on indirect field observations of proximal structures. Elevation data will need to be confirmed by land survey in a subsequent phase of design.

[3] http://www.mafishfinder.com/hopedale-pond-25007-location.html

Hopedale Pond is a feature of the Parklands. The Parklands is an approximately 273-acre park in the northwest area Hopedale. It stretches from the corner of Dutcher and Freedom Streets north of the Draper plant, encompasses the area around Hopedale Pond. The Parklands include a bathing beach, bathhouse, picnic tables, and a boat ramp. The Parklands was designed by landscape architect Warren Henry Manning and built between 1899 and 1914 (Massachusetts Heritage Landscape Inventory Program, 2007). As noted in the Town's Plan of Conservation and Development, "the Parklands and Hopedale Pond are key resources that provide opportunities for hiking, fishing, swimming, boating, nature study, and passive recreational activities" (Town of Hopedale, 2004, p.64).

Figure 1—Dutcher Street Outfall at Hopedale Pond

There is extensive weed growth in the pond. Hopedale Pond is on the Integrated List of Waters in Category 4c - Impairment Not Caused by a Pollutant, which is the result of infestation by a nonnative aquatic macrophyte, primarily variable-leaf milfoil. In 2001, Massachusetts Department of Environmental Protection *Water Quality Assessment Report* assessed the pond as eutrophic.

The Hopedale Pond has been the subject of a number of studies in recent years. This section of our report focuses on the diagnostic and feasibility study that ESS conducted in 2009. This study reviewed both dry-weather and wet-weather sources. In general the study found the most significant wet- and dry-weather contributions of *E. coli*, nitrogen, and phosphorus at Site 4, which is the Dutcher Street Outfall. The table below represents mean and peak levels for *E. coli* at Site 4.

Table 2.1
Peak and Mean Concentrations of *E. Coli* at the
Dutcher Street Outfall during Dry and Wet Weather

Parameter	Dry-Weather		Wet-Weather	
	Mean	Peak	Mean	Peak
E. coli	429 cfu/100mL[a]	>20,000 cfu/100mL	379 cfu/100mL	3,000 cfu/100mL

Notes:

a. "cfu" means colony forming units.

E. coli was found at over 20,000 colonies per 100mL during dry weather and over 3,000 colonies per 100mL during wet weather. As a result, the Town is currently pursuing both dry- and wet-weather mitigation programs.

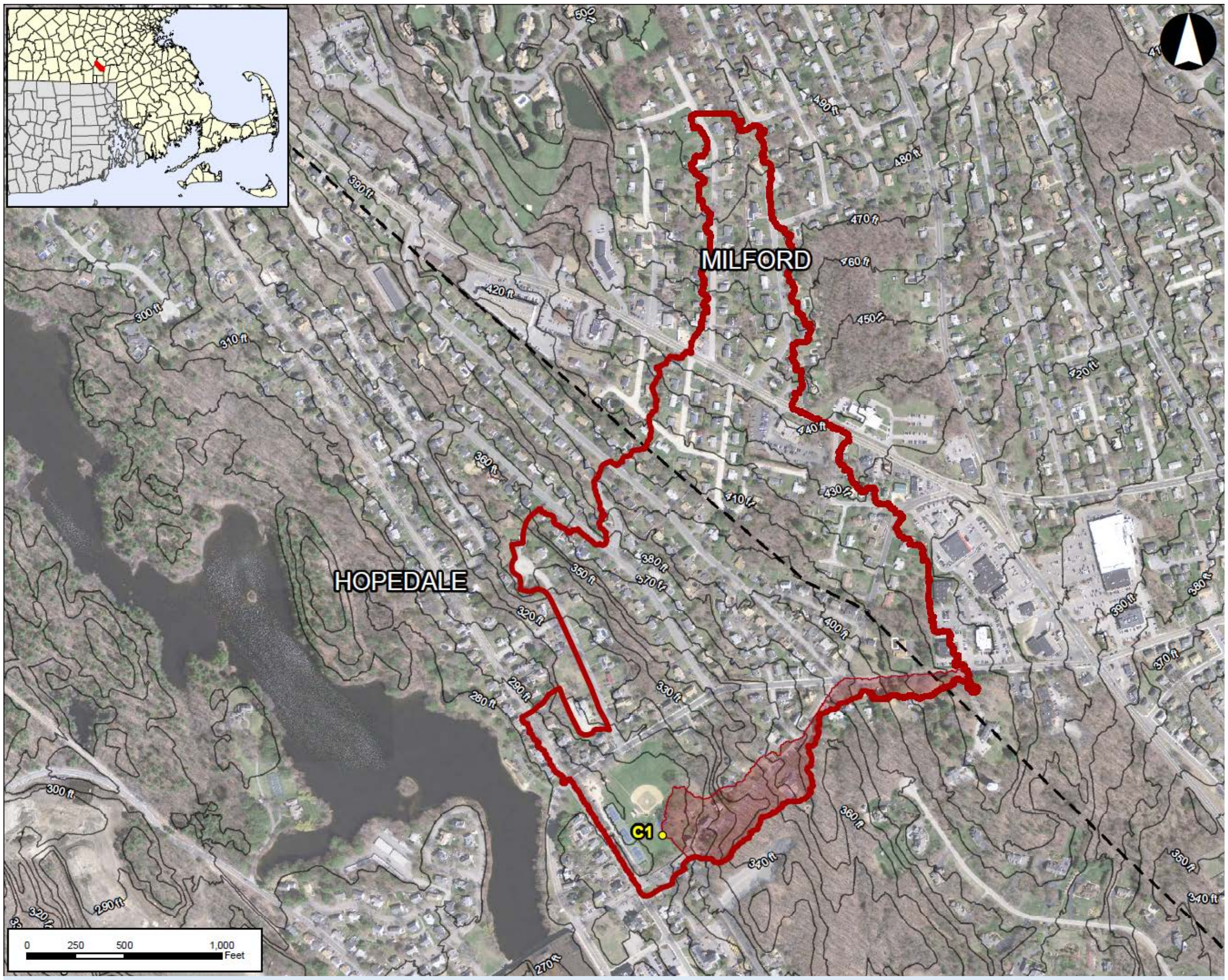

Figure 2—Drainage Catchment for Site C1 in the Hopedale Pond Watershed. The C1 drainage catchment (shaded in red) is on the southeast side of the Dutcher Street Outfall drainage area.

3.0 CURRENT WATERSHED CONDITIONS AND EXISTING STORMWATER INFRASTRUCTURE

Section 3.0 provides a discussion of watershed data including land use, cultural resources and habitat and soils. This section also discusses stormwater infrastructure data that is available from the Town. The purpose of this discussion is to provide information to support the conceptual design of structural BMPs.

3.1 Land Use

Land-use data was obtained from MassGIS. The information is derived from 2005 orthophotographs and covers the entire state at increments ranging from 0.25 to 1 acre. As shown in Table 3.1 below, residential areas make up over 75% of the total watershed area of interest, followed by undeveloped/rural areas which account for just under 20% and a small amount of commercial properties contributing around 4%. For modeling purposes the land use classifications have been grouped from the original designations in the 2005 land use data into slightly broader categories used for the runoff and pollution generation calculations. The land use data was broken down by individual subbasin to refine the model and resulting pollutant loads for specific areas, as seen in Tables 3.1 and 3.2.

Table 3.1
Land Use Breakdown in the Hopedale Watershed Area of Interest
(Entire Subject Area – 94.6 acres)

Land Use Classification	Percentage of Watershed by Area
Commercial	4.1%
Residential	77.7%
Undeveloped/Rural	18.2%
Total	**100.0%**

Table 3.2
Land Use Breakdown in Basin C1 (7.3 acres) of The Hopedale Watershed Area of Interest

Land Use Classification	Percentage of Watershed by Area
Commercial	0.1%
Residential	51.1%
Undeveloped/Rural	48.8%
Total	**100.0%**

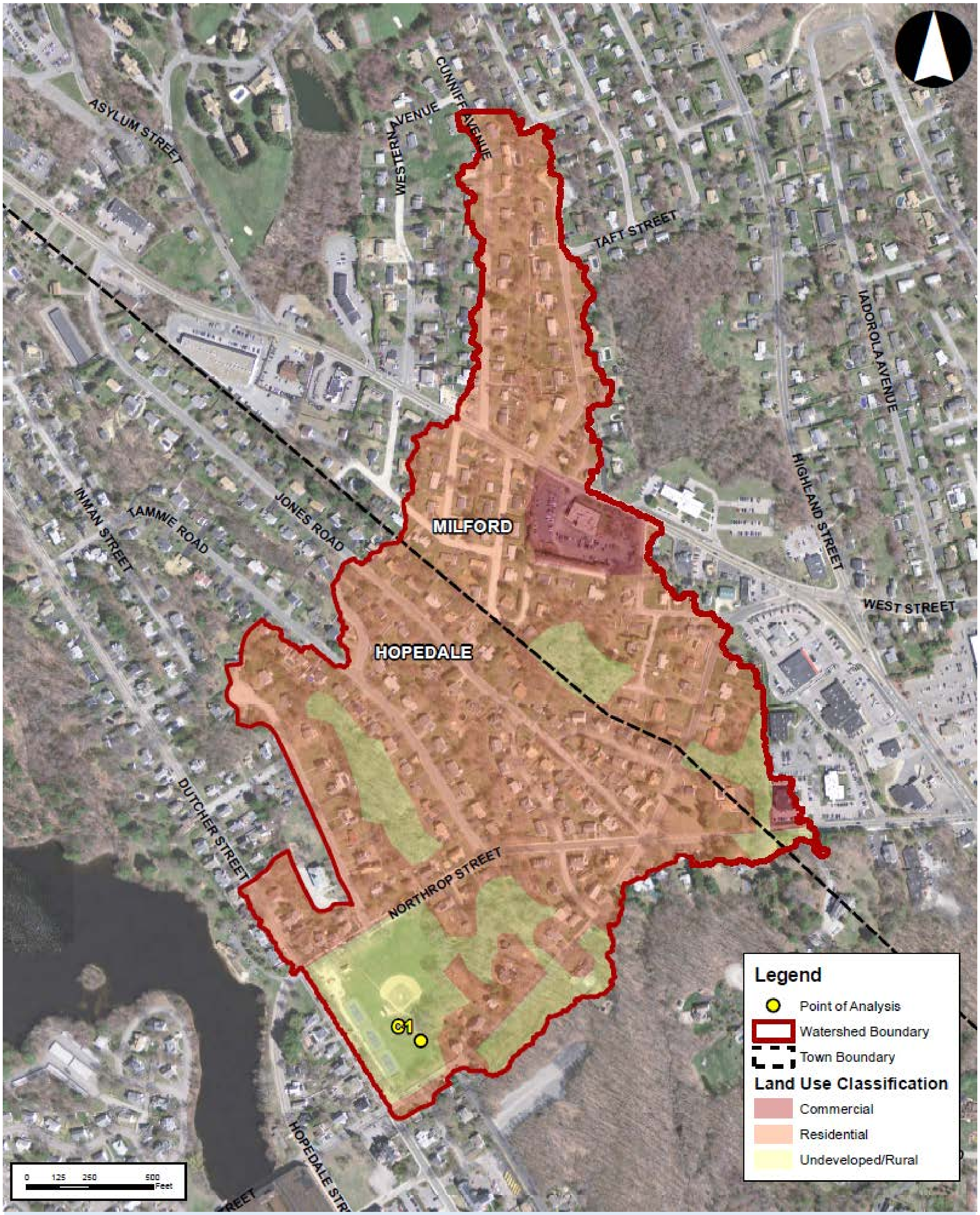

Figure 3—Land Use in the Dutcher Street Subject Outfall Watershed to Hopedale Pond.

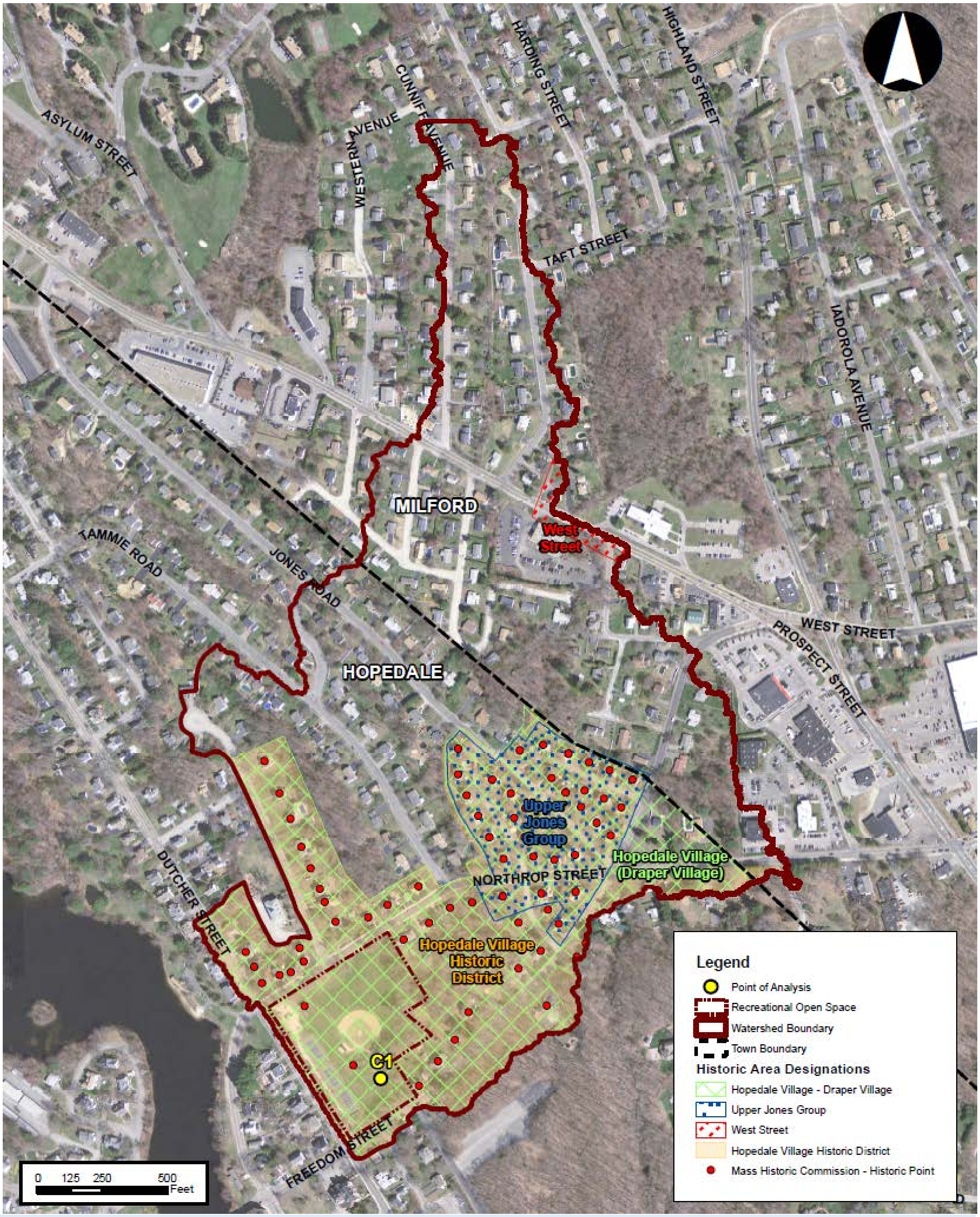

Figure 4—Cultural Resources in the Dutcher Street Subject Outfall Watershed to Hopedale Pond.

3.2 Habitat and Cultural Resources

To determine the existence of cultural resources within the watershed the following sources were consulted:

- The National Register of Historic Places database.
- Massachusetts Historic Commission Inventory (MACRIS database).

3.3 Soils

3.3.1 MassGIS Data

To make an initial determination of soil types within the watershed area, a SSURGO-certified data layer published by MassGIS originally from the U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS), was consulted. Hydrologic soil groups of A and B type soil are considered to be supportive of infiltration systems at the conceptual design level. The following table breaks down the distribution of hydrologic soil types.

Table 3.3
Hydrologic Soil Groups in the Hopedale Section of the Hopedale Pond Watershed

Hydrologic Group	Percentage	General Distribution in Watershed
A	4.2%	Located close to pond near outfall location
B	20.4%	Park and strip of residential land running NW to SE through basin
C	75.4%	Majority of the Northern portion of the watershed
D	NA	None found in subject watershed

According to NRCS data, the main soil types found within the watershed of interest are the Paxton-Urban Land Complex (71.5%), the Chatfield-Hollis-Rock Outcrop Complex (16.0%), Udorthents smoothed (4.3%), and the Hinckley-Urban Land Complex (4.2%). Hydrologic Soils Groups (HSG) A and B are ideal candidates for infiltration BMP practices, which are especially effective at pollutant removal. Although only 24.6% of the subject watershed contains HSG A and B soils, the proximity of those soils to the outfall and to publicly owned parcels enables the consideration of infiltration BMPs. Table 3.3 above describes the general soil types and Figure 5 shows their distribution within the watershed.

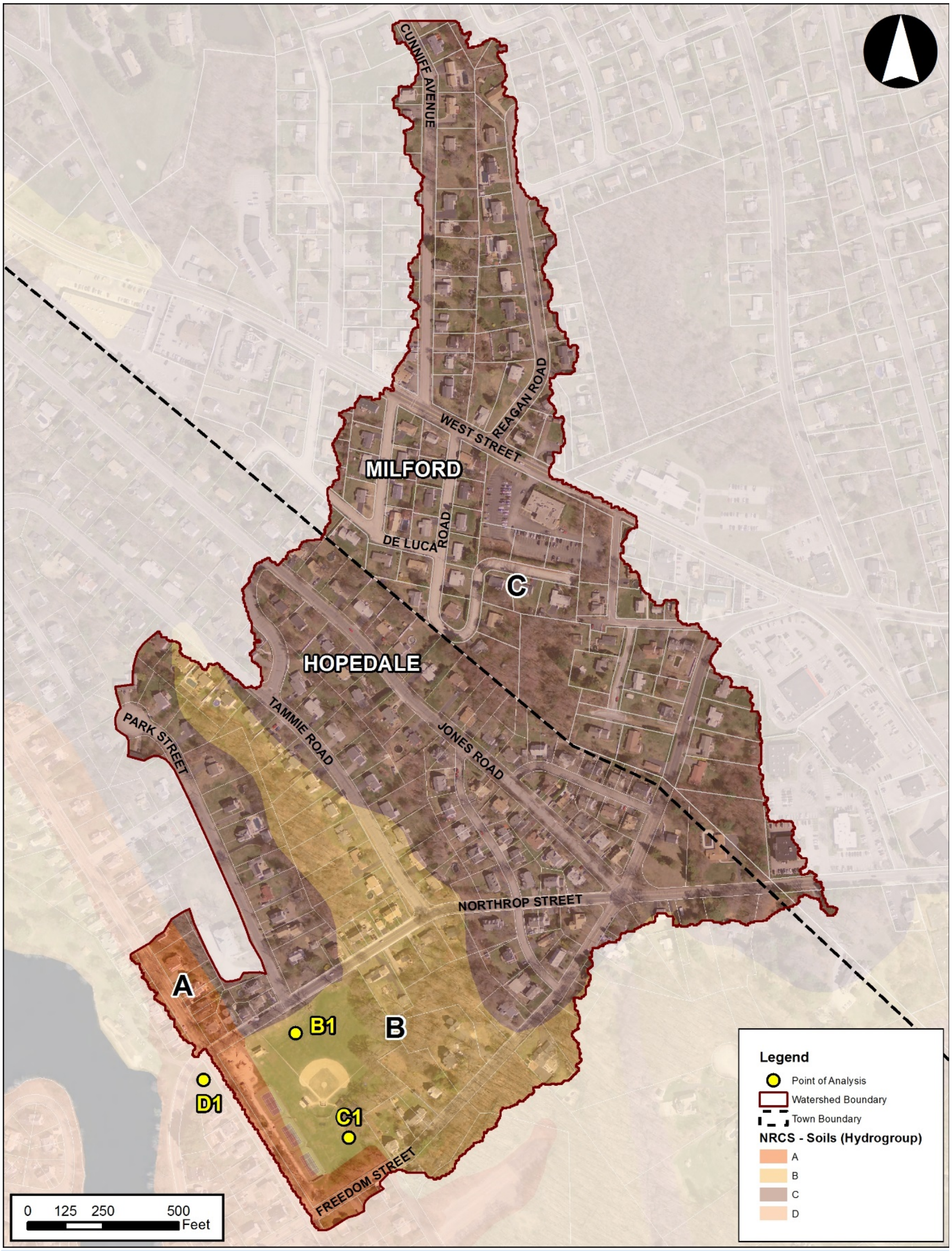

Figure 5—Hydrologic Soils Types

3.3.2 Field Investigation of Soils

Figure 6—Location of the soil test pit (approximately to the left of the backhoe).

Figure 7—Excavation of the soil test pit.

To confirm the NRCS soils data in accordance with MassDEP stormwater design standards, ESS staff conducted a field evaluation using a soil test pit. The soil test pit evaluation was conducted on the morning of Tuesday, November 17, 2015. Based on NRCS soil mapping, soils within the park, including the soil test pit location and the proposed subsurface infiltration BMP location, are smoothed Udorthents. Smoothed Udorthents are typically very deep soils that are characterized by human disturbance – specifically excavation and filling, which can range from 2 to 20 feet below the ground surface. However, due to the large amount of variability within this group, field surveys are needed to adequately classify the soils (NRCS 1998).

Figure 8—Characterization of the soil test pit.

ESS performed one soil test pit located in the southeastern potion of the park in an open grassy area to the east of the tennis courts and to the south of the baseball field and basketball court (see Figure 6, above). The soil test pit was located approximately 280 feet northeast of the park entrance at the corner of Dutcher Street and Freedom Street. The soil test pit was excavated to the required depth of 9 feet below ground surface. The depth of the soil test pit was confirmed using a measuring tape.

ESS characterized the soil with regard to texture, color, presence and extent of redoximorphic features, depth of saturation, and depth to free water. The characterization was conducted from within the soil test pit using a ladder. Soil texture was characterized using the standard soil texture triangle. Soil color was determined using the Munsell Soil Color Chart, 1994 revised edition.

Soils within the excavated soil test pit were primarily dark brown and grayish brown silty loam within 16 inches of the surface, and were light gray fine sandy silty loams and clayey silty loams from 24 inches (2 feet) feet to 108 inches (9 feet) below the surface. Redoximorphic features began at 16 inches below the surface and continued to the bottom of the soil test pit. Soil saturation was noted at 66 inches (5.5 feet) below the surface, and free water was present at 108 inches (9 feet). A test pit boring log with details regarding the characteristics of the soil profile is provided in Appendix A.

3.4 Field Investigation of Wetlands

Initial investigation of wetlands using MassGIS found no wetland resources within the proposed site watershed boundary. This was confirmed by an ESS wetland scientist on a site walk on Tuesday, November 17, 2015. No proposed project conveyances are anticipated to adversely affect wetlands or receiving waters of the Commonwealth.

4.0 ANALYSIS OF HYDROLOGY AND HYDRAULICS

We conducted a hydrologic assessment of the drainage area to point of analysis C1 (see Figure 2, above), where a BMP is proposed to be sited. We used TR-55 graphical method and analyzed the water quality event, Type III 24-hour 2-year, 10-year, and 100-year storms. Rainfall data was collected from the most recent NOAA Atlas 14 Point Precipitation Frequency Estimates. The proposed BMP is sized to capture the required water quality volume, which per *Massachusetts Stormwater Handbook*, is equal to 1 inch of runoff over the impervious surface. A summary of peak discharge volumes is shown in the table below.

Table 4.1
Hydrologic Analysis of Basin C1

Drainage Area (ac)	Impervious Area (ac)	WQV[a] (cf)	Peak Discharge Volumes (cfs)			
			Water Quality Event[b]	2-year	10-year	100-year
7.3	1.78	6461	1.18	1.48	1.59	1.72

Notes:
a. "WQV" means water quality volume.
b. The water quality event is the 24-hour wet-weather that is anticipated to generate the water quality volume from an impervious surface. Based on TR-55 the water quality event is equal to 1.2 inches of rain.

5.0 PROPOSED RETROFITS

This section discusses proposed drainage system retrofits to the Freedom Street drainage system as well as installation of a bioretention system in Hopedale Town Park. A detailed cross section and plan view of the proposed system and bioretention field is provided in Appendix B.
Calculations for the bioretention pretreatment field and pipes sizing are provided in Appendix C.

5.1 Drainage Routing

Conceptual design work conducted as part of *Hopedale Pond Storm Drain Mapping, Conceptual Stormwater Designs and Sampling* (ESS 2015) determined that flow from the pipe network on Freedom Street could probably be rerouted to discharge to a proposed BMP at point of analysis C1. Drainage rerouting design has been advanced as part of our budget-level design and is in this section.

A proposed manhole will be installed to the east of existing catch basin FR3.The proposed manhole is expected to have a rim elevation of approximately 305.0 feet.[4] An existing 24-inch, which drains Freedom Street to Dutcher Street, will be used to pass flows greater than the peak of the water quality event. An 8-inch reinforced concrete pipe is proposed for installation with its invert at elevation 300.0 and its top just below the invert of the existing 24-inch pipe. The 8-inch pipe has been sized to pass the peak flow of the water quality event (i.e., 1.18 cfs) to the bioretention system. This rerouting is intended to allow the bioretention system to function as an offline BMP. The proposed 8-inch pipe from Freedom Street will outlet at the end of an existing retaining wall between the north side of Freedom Street and the adjacent boundary of Hopedale Park. The proposed pipe will outlet to the bioretention energy dissipation and pretreatment system at an approximate elevation of 299.6. (See Section 5.0 for discussion of the pretreatment and bioretention system.)

An existing yard drain (i.e., catch basin), PAR2, which is at the southeast entrance to the park, will collect flow discharged from the bioretention system. Normal flows from the bioretention system will discharge to PAR2 through an 8-inch subdrain. The bioretention system design also includes an emergency overflow spillway, which will be armored with a geogrid to allow for grassed cover while preventing overflow scour.

5.2 Pretreatment and Bioretention Features

A grassed filter strip will be used to pretreat flow from the level spreader before entering the bioretention basin. The filter strip will be 25 feet in length and built at a 2 percent slope. Riprap, acting as an energy

[4] Elevation data was interpolated based on indirect field observations of proximal structures. Elevation data will need to be confirmed by land survey in a subsequent phase of design.

dissipator followed by a stone diaphragm level spreader, will distribute runoff from Freedom Street as sheet flow to the grassed filter strip.

Bioretention areas provide water quality treatment through filtration, microbe activity, and nutrient uptake by plants. The bioretention system has been sized to treat a water quality volume (i.e., the first 1-inch of runoff) and designed to drain within 48 hours. Overall, the proposed bioretention basin will have a footprint of approximately 4 percent of the contributing drainage area.

The bioretention basin will provide a ponding depth of 6 inches. To allow continued use of the BMP area as an athletic field, the bioretention basin will be grassed with a native New England seed mix and will be bordered with 5:1 side slopes. The bioretention subgrade will include 30 inches of planting soil. Soil media to a depth of 30 inches provides nitrogen removal. A geomembrane liner will be placed at the bottom of the subgrade under the entire bioretention basin. Designs include an underdrain system with underdrain pipes spaced at 10 feet on center. Eleven parallel (6-inch diameter PVC) perforated underdrains will be installed at the bottom of the bioretention basin. The bioretention underdrain system is designed to meet the flow-through capacity of the filter media, assuming 50 percent of the perforations is lost due to clogging over time. The underdrain system is sized to ensure the runoff within the bioretention system drains within 48 hours. Treated water will discharge through a 12-inch diameter pipe to existing catch basin PAR2. An emergency spillway will be installed at the bioretention basin outlet to pass flows in the event of an overflow of the basin.

5.3 Landscaping

Developing an effective landscaping plan is essential to the success of the stormwater management system. The proposed seed mix for the bioretention basin, grassed filter strip, and emergency outlet are presented in Table 5.1 and were selected based on a specified zone of hydric tolerance and capabilities of surviving both wet and dry conditions. The seed mix can be applied by hydro-seeding, by mechanical seeding, or by hand on clean weed-free bare soil bed. Generally, this mix is slow to germinate during the first year of planting and will establish good cover by the second growing season. Additionally, Creeping Red Fescue and Virginia Wild Rye offer sediment control. This seed mix is intended to provide pollutant uptake with minimal need for fertilization and maintenance. It will accommodate heavy foot traffic and general athletic use of Hopedale Park.

Table 5.1
New England Native Custom Cold Season Grass Mix

Scientific Name	Common Name	Indicator
Schizachyrium scoparium	Little Bluestem	FACU
Elymus virginicus	Virginia Wild Rye	FACW-
Andropogon gerardii	Big Bluestem	FAC
Sorghastrum nutans	Indian Grass	UPL
Festuca rubra	Creeping Red Fescue	FACU
Panicum virgatum	Switch Grass	FAC

Hopedale recognizes that bioretention typically relies on deeper-rooted vegetation (i.e., as opposed to grass). Vegetation with deeper root systems generally provides more effective nutrient uptake; however, a mix of grass was chosen to accommodate existing athletic uses of the BMP site.

5.4 Operation and Maintenance

The Operations and Maintenance (O&M) Plan for the Hopedale Green Infrastructure Design has been prepared in compliance with Standard 9 of the Massachusetts Stormwater Handbook dated February 2008.

Bioretention areas require routine maintenance to maximize water quality treatment and effective stormwater management. Proper maintenance of the BMP will help maintain an aesthetic quality compatible with surrounding land uses.

Upon installation, the basin should be inspected as necessary for sediment backup, eroded areas, standing water and removal of trash and dead vegetation. Soil must be covered with 2 inches of fine-shredded hardwood mulch. Snow maintenance on site is limited to plowing along access paths. The owner shall be responsible for routine maintenance and accurate records of all inspections as described in the provided schedule in Table 5.2.

Table 5.2
Operations and Maintenance Schedule

Activity	Inspection Frequency
Mulch	Annually
Fertilize	Annually
Prune	Annually
Remove dead vegetation and replace media	As necessary
Mow	Two to twelve times per year
Inspect and remove trash	Monthly

5.5 Opinion of Cost

The anticipated cost was tabulated from the 2014-2015 “Weighted Bid Prices” module in the Construction Project Estimator developed by Massachusetts Department of Transportation – Highway Division. The preliminary estimate of quantities for the elements in the BMP design, including a 25 percent contingency, is shown in Appendix C. Unit costs for preferred BMPs in dollars per cubic foot (cu ft) area listed in Table 5.3 below. This table also shows percent pathogens reduction considering unit costs in conjunction with pollutant removal rate.

Table 5.3
Opinions of Cost

Point of Analysis	Treatment Site (Plat_Lot)	Percent Reduction for BMP Drainage Area	Total Reduction (trillion colonies/year)	Anticipated Cost of BMPs	
				Low Cost	High Cost
C1	8-29-0	90.3%	8	$165,000	$207,000

The design of grassed bioretention with a liner in place of subsurface infiltration will slightly increase the cost of the project. Additionally, MassDEP requires soil media at a depth of 30 inches to achieve adequate pollutant removal, specifically nitrogen. Typically, the depth of soil media in bioretention design is between one to two feet. Excavation greater than two feet becomes more expensive.

5.6 Anticipated Water Quality Benefits and Cost-Benefit Analysis

Based on desktop analysis, three key discharge points have been identified in the area of interest in the Hopedale watershed. A pollutant loading analysis using the Simple Method from the *Rhode Island Stormwater Design and Installation Standards Manual* (December 2015) (RISDISM) was completed for each of the three points of analysis.

The tables below summarize the estimated annual Nitrogen loads of the bioretention system proposed for Point of Analysis C1. The Excel spreadsheet used to calculate pollutant loads can be found in Appendix A.

Table 5.4
Percent Pathogen Reduction in Stormwater Drainage Areas

Point of Analysis	Treatment Site (Plat_Lot)	Percent Pathogen Reduction in Area Draining to Treatment Site			Percent Reduction for BMP Drainage Area
		Bioretention	WVTS	Sand Filter	
C1	8-29-0	90.3%			90.3%

6.0 NEXT STEPS

The Town has previously conducted optical brightener investigations of the storm drain in order to identify potential illicit discharges. No illicit discharges have been identified; however likely mammalian sources of pathogens (bats and dogs) were identified. The Town also found elevated concentrations of pathogens from a connection apparently originating from north of the Hopedale-Milford boundary. Hopedale plans to address this with Milford officials and request their participation in the Hopedale Pond stormwater abatement initiative.

Hopedale has contacted Milford and informally discussed partnering on the project. Hopedale submitted a letter of interest (LOI) to the Environmental Protection Agency Region 1 (EPA-R1) for a grant that would involve partnership with Milford on stormwater improvements. Unfortunately, the LOI was not selected for the full application process. Nevertheless, the Town anticipates continuing to pursue funding opportunities as they arise. For example, Hopedale submitted a grant application to the Massachusetts Department of Environmental Protection Nonpoint Source Management Program on June 2, 2015, but did not receive funding. Hopedale is in the process of planning a request for bond funds through a local warrant.

We recommend the following next steps and schedule for implementation of bioretention at point of analysis C1. Implementation of BMPs throughout the Dutcher Street Outfall Catchment is described in *Hopedale Pond Storm Drain Mapping, Conceptual Stormwater Designs and Sampling* (ESS 2015).

Table 6.1
Schedule of BMP Implementation with
Measures of Success and Probable Costs

Program Year	Structural BMPs	Evaluation Measure	Probable Cost Range (total, rounded to 1,000s)
Year 1	• Design and Permit BMPs for points C1	• BMP designed • BMP permitted	$20,000 – $30,000
Year 2	• Implement BMPs for Point C1	• Number of BMPs installed	$165,000 – $207,000

7.0 REFERENCES

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National Oceanic and Atmospheric Administration (2015). Precipitation Frequency Data Server, NOAA Atlas 14, Volume 10, Version 2.

RIDEM. (2010). *Rhode Island Stormwater Design and Installation Standards Manual*.

Appendix A

Soil Evaluation Data

TEST PIT LOG

	SITE: Hopedale Park (Site C1)	**TEST PIT NO.:** 1
	DATE: 11/17/15	**WEATHER: Sunny, light wind, 40s**
	CLIENT: Hopedale Park Commission	**ESS INSPECTOR: Patterson**
	TOTAL DEPTH OF EXCAVATION: 9 ft	**SURFACE ELEVATION:** NM
	EXCAVATION METHOD: Backhoe	**DEPTH TO WATER:** 9 ft
	SUBCONTRACTOR: N/A	**ESS JOB NO.:** H172-001.03

Sample No. (depth)	Headspace (ppm)	Depth (feet)	Lab Analysis	**Materials Description** Color, density (refer to charts below), size, major and minor constituents, moisture (dry, damp, moist, wet)	Notes
		0.5		0" – 10": 10 YR 3/3 100% (matrix); dark brown silty loam	
		1.0		10" – 16": 10 YR 5/2 100% (matrix); grayish brown file sandy silty loam	
		1.5 – 5		16" – 108": 10 YR 7/1 70% (matrix); 10 YR 6/8 20% (concentrations); 10 YR 8/1 10% (depletions); light gray fine sandy silty loam and light gray clayey silty loam	
		5.5 – 7			
		7.5 – 10			
		10.5			

SITE SKETCH

TEST PIT SKETCH

COMMENTS:

GRANULAR SOILS COHESIVELESS DENSITY

0-4	Very Loose
5-9	Loose
10-29	Medium Dense
30-49	Dense
50+	Very Dense

PLASTIC SOILS COHESIVE DENSITY

0-2	Very Soft
3-4	Soft
5-8	Medium Stiff
9-15	Stiff
16-30	Very Stiff
31+	Hard

PROPORTIONS USED

Trace	0-10%
Little	10-20%
Some	20-35%
And	35-50%

LEGEND:

ND =	Not Detected
NA =	Not Applicable
GS =	Ground Surface
NM =	Not Measured

Appendix B

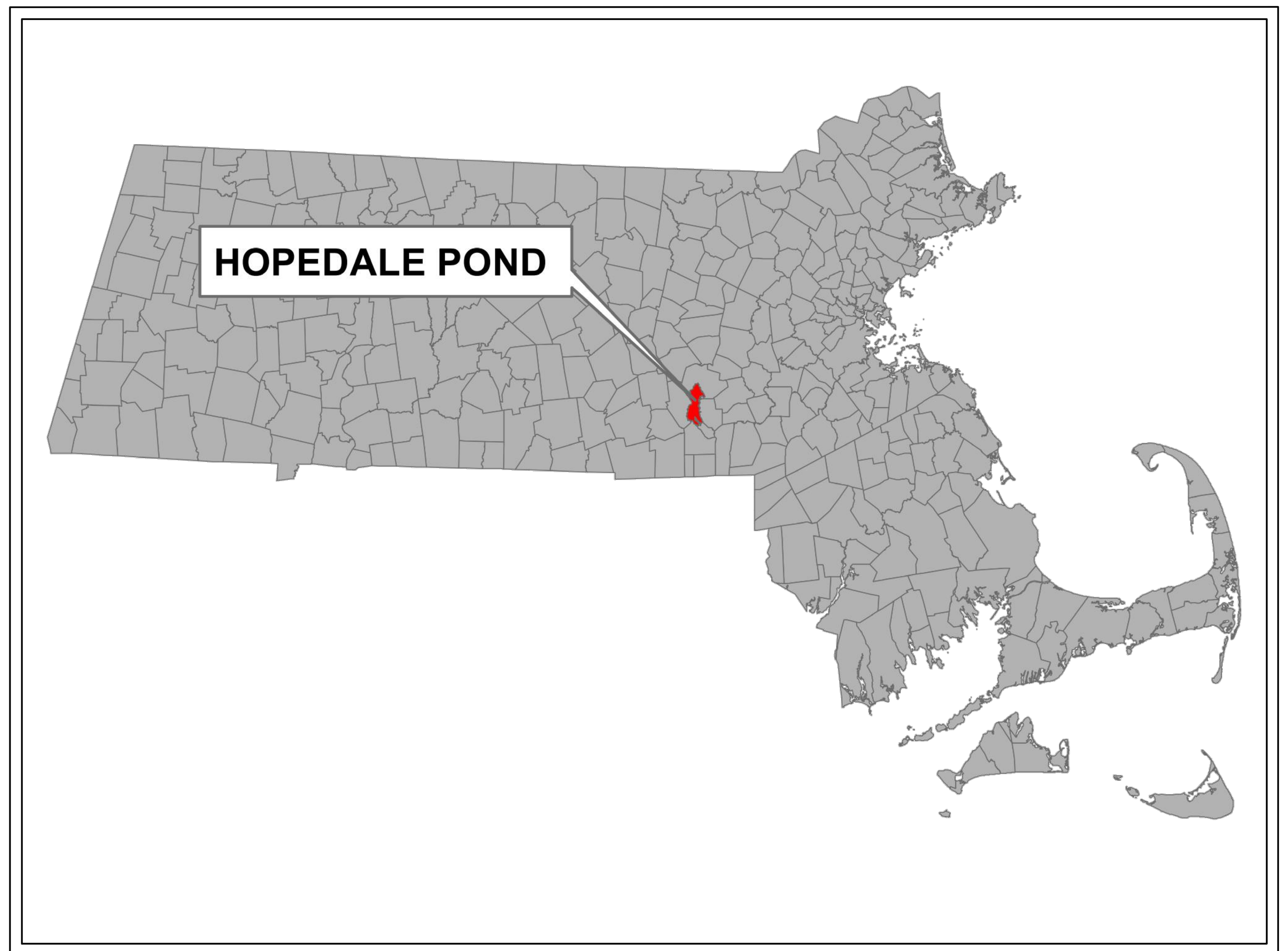
Design Set

SITE PLANS FOR
HOPEDALE POND GREEN INFRASTRUCTURE DESIGN

HOPEDALE POND

TOWN OF HOPEDALE PARK COMMISSION

DECEMBER 2015



SITE LOCUS MAP

SOURCE: MassGIS

PREPARED BY:

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INDEX OF DRAWINGS

PRELIMINARY - NOT FOR CONSTRUCTION

GENERAL NOTES:

1. SOIL TEST PIT EVALUATION CONDUCTED ON NOVEMBER 17, 2015. ESS PERFORMED ONE SOIL TEST PIT APPROXIMATELY 280 FEET NORTHEAST OF HOPEDALE PARK ENTRANCE AT THE CORNER OF DUTCHER STREET AND FREEDOM STREET. PHOTOGRAPHS AND DETAILED INFORMATION OF SOIL CHARACTERISTICS IN "HOPEDALE POND GREEN INFRASTRUCTURE DESIGN (SITE C1)" PREPARED BY ESS GROUP, DATED JANUARY 2016.
2. SOURCE OF TOPOGRAPHIC INFORMATION IS FROM 2013-2014 MASSGIS LIDAR TERRAIN DATA .
3. THE DATUM REFERENCES NAD83 MASSACHUSETTS STATE PLANE COORDINATES.
4. ACCORDING TO NATURAL RESOURCES CONSERVATION SERVICE (NRCS) DATA, THE MAIN SOIL TYPES FOUND WITHIN THE HOPEDALE POND WATERSHED OF INTEREST ARE PAXON-URBAN LAND COMPLEX (71.5%), THE CHATFIELD-HOLLIS-ROCK OUTCROP COMPLEX (16.0%), UDORTHENTS SMOOTHED (4.3%), AND THE HINCKLEY-URBAN LAND COMPLEX (4.2%).

BIORETENTION NOTES:

BIORETENTION SOIL MIX SHALL HAVE A LOAMY SAND TEXTURE PER USDA TEXTURAL TRIANGLE WITH A MAXIMUM CLAY CONTENT OF LESS THAN 2%. SOIL MIXTURE SHALL BE 85-88% SAND, 8-12% SOIL FINES, AND 3-5% ORGANIC MATTER.

THE SOIL SHALL BE UNIFORM MIX, FREE OF STONES, STUMPS, ROOTS, OR OTHER SIMILAR OBJECTS LARGER THAN TWO INCHES, SOIL SHALL BE FREE OF BERMUDA GRASS, QUACKGRASS, JOHNSON GRASS, MUGWORT, NUTSEDGE, POISON IVY, CANADIAN THISTLE, TEARTHUB, OR OTHER NOXIOUS WEEDS.

PRIOR TO INSTALLATION, SOIL SHALL BE TESTED AND CONFORM TO THE FOLLOWING CRITERIA.

PH RANGE: 5.7 - 7.0
MAGNESIUM: NOT TO EXCEED 32 PPM
PHOSPHORUS P205: NOT TO EXCEED 69 PPM
POTASSIUM K20: NOT TO EXCEED 78 PPM
SOLUBLE SALTS: NOT TO EXCEED 500 PPM

LEGEND

EXISTING CONTOUR (2' INTERVAL)

TEST PIT

GRAVEL

SUBGRADE

CONCRETE

FLOW ARROW

PROPOSED STORM SEWER MANHOLE

PROPOSED BIORETENTION BASIN

EXISTING PIPE (DIAMETER AND TYPE AS SPECIFIED)

PROPOSED PIPE (DIAMETER AND TYPE AS SPECIFIED)

PRELIMINARY - NOT FOR CONSTRUCTION

ess group
environmental consulting & engineering services

10 Hemingway Drive, 2nd Floor
East Providence, Rhode Island 02915
p: 401.434.5560
www.essgroup.com

No.	REVISION	DATE	APP BY

DRAWN BY: BL	CHECKED BY: MJR
DESIGNED BY: BL	APPROVED BY: PRW

Town of Hopedale
Park Commission
Hopedale, MA

Hopedale Pond
Green Infrastructure Design
General Notes and Legend

PROJECT No.: H172-001	DRAWING No.
DATE OF ISSUE: 12/2015	**1**
SHEET No.: 1	
SCALE:	

PRELIMINARY - NOT FOR CONSTRUCTION

ess group
environmental consulting & engineering services

10 Hemingway Drive, 2nd Floor
East Providence, Rhode Island 02915
p: 401.434.5560
www.essgroup.com

No.	REVISION	DATE	APP BY

DRAWN BY: BL	CHECKED BY: MJR
DESIGNED BY: BL	APPROVED BY: PRW

Town of Hopedale
Park Commission
Hopedale, MA

Hopedale Pond
Green Infrastructure Design
Existing Conditions

PROJECT No.: H172–001	DRAWING No.
DATE OF ISSUE: 12/2015	**2**
SHEET No.: 2	
SCALE: 1"=20'	

NOTES:

1. PROPOSED BIORETENTION BASIN DESIGNED WITH PONDING DEPTH OF 6 INCHES AND 2 INCHES OF FREEBOARD.
2. BIORETENTION SYSTEM WILL BE LINED WITH AN IMPERMEABLE MEMBRANE TO PREVENT GROUNDWATER UPWELLING. THE SURFACE WILL BE APPLIED WITH NEW ENGLAND NATIVE CUSTOM COLD SEASON GRASS MIX FOR GENERAL ATHLETIC USE.
3. EMERGENCY SPILLWAY WILL BE DESIGNED IN A SUBSEQUENT PHASE OF DESIGN WORK TO MANAGE THE 10-YEAR PEAK FLOW.
4. INSPECT SUBDRAIN LINES AT PAR2 FOR BLOCKAGE AND CLEAN AS NECESSARY.

PRELIMINARY - NOT FOR CONSTRUCTION

ess group
environmental consulting & engineering services
10 Hemingway Drive, 2nd Floor
East Providence, Rhode Island 02915
p: 401.434.5560
www.essgroup.com

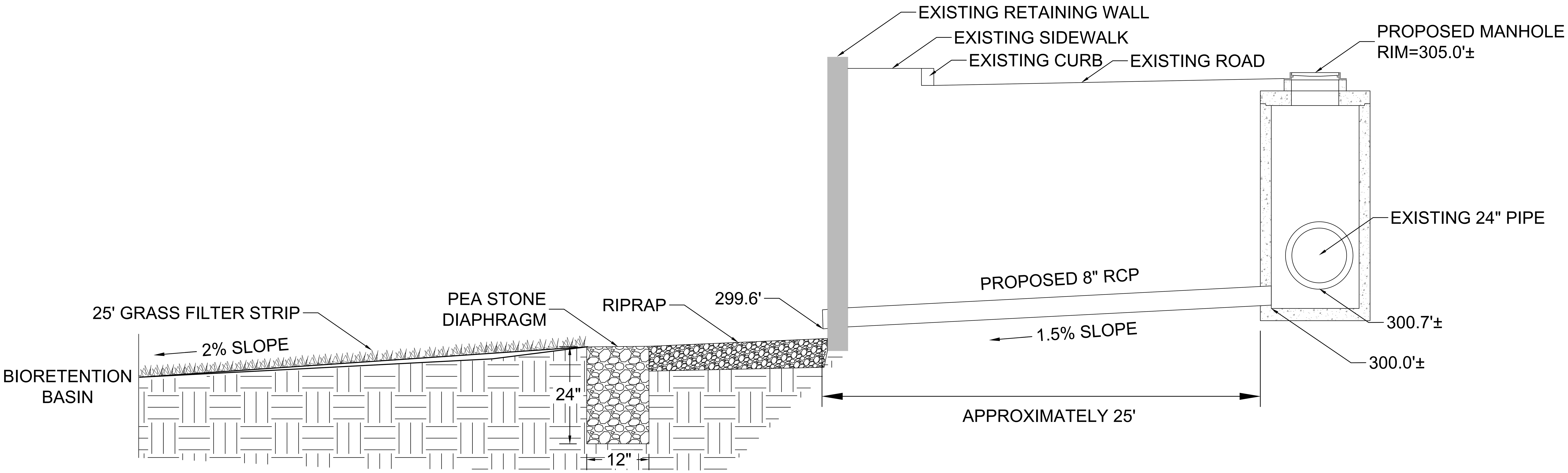
No.	REVISION	DATE	APP BY

DRAWN BY: BL	CHECKED BY: MJR
DESIGNED BY: BL	APPROVED BY: PRW

Town of Hopedale
Park Commission
Hopedale, MA

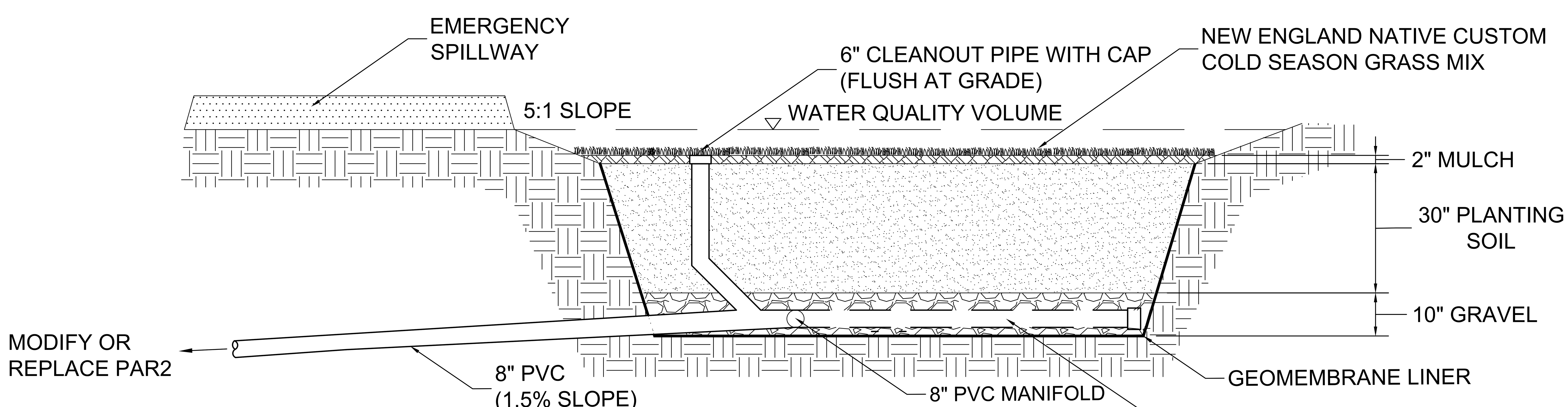
Hopedale Pond
Green Infrastructure Design
Proposed Conditions

PROJECT No.: H172–001	DRAWING No.
DATE OF ISSUE: 12/2015	**3**
SHEET No.: 3	
SCALE: 1"=20'	



4 A BIORETENTION PRETREATMENT PLAN VIEW

NOT TO SCALE



4 B BIORETENTION BASIN PLAN VIEW

NOT TO SCALE

PRELIMINARY - NOT FOR CONSTRUCTION

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environmental consulting
& engineering services

10 Hemingway Drive, 2nd Floor
East Providence, Rhode Island 02915
p: 401.434.5560
www.essgroup.com

No.	REVISION	DATE	APP BY

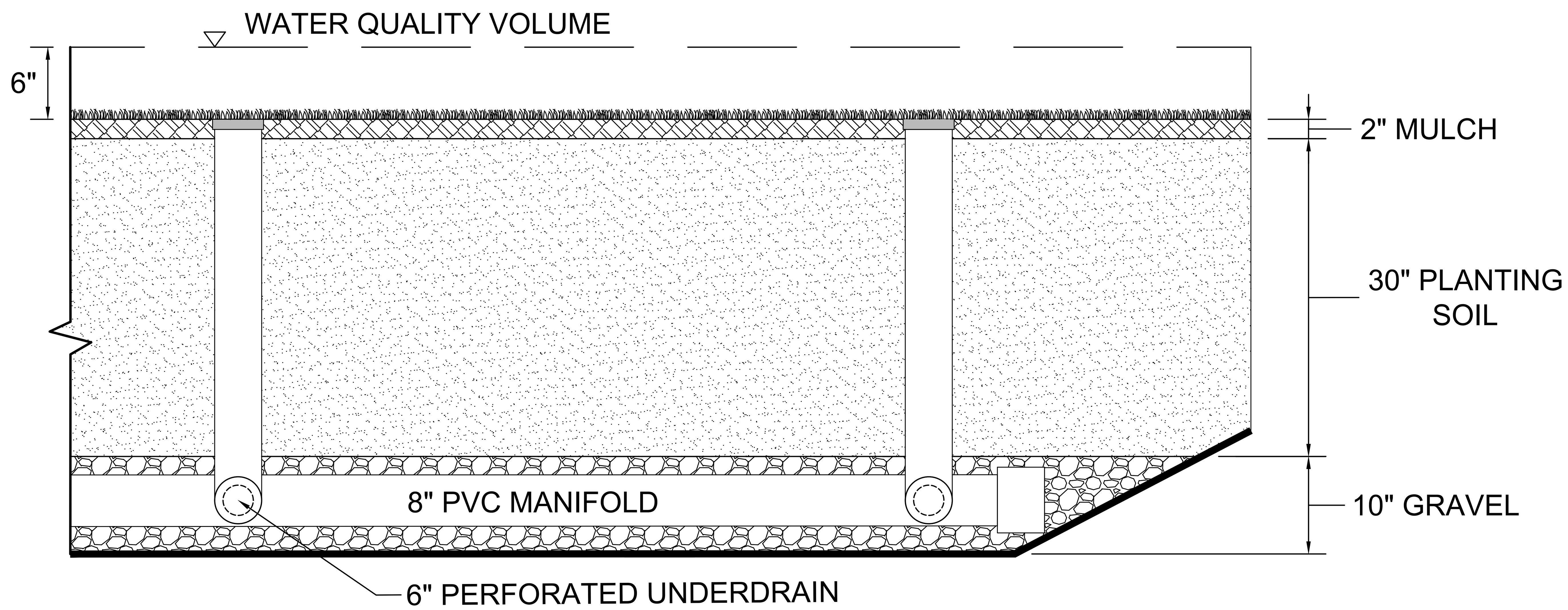
DRAWN BY: BL | CHECKED BY: MJR
DESIGNED BY: BL | APPROVED BY: PRW

Town of Hopedale
Park Commission
Hopedale, MA

Hopedale Pond
Green Infrastructure Design
Details

PROJECT No.: H172-001
DATE OF ISSUE: 12/2015
SHEET No.: 4
SCALE:

DRAWING No.
4



5 / A

BIORETENTION BASIN CROSS SECTION

NOT TO SCALE

PRELIMINARY - NOT FOR CONSTRUCTION

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environmental consulting & engineering services

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East Providence, Rhode Island 02915
p: 401.434.5560
www.essgroup.com

No.	REVISION	DATE	APP BY

DRAWN BY: BL | CHECKED BY: MJR
DESIGNED BY: BL | APPROVED BY: PRW

Town of Hopedale
Park Commission
Hopedale, MA

Hopedale Pond
Green Infrastructure Design
Details

PROJECT No.: H172-001
DATE OF ISSUE: 12/2015
SHEET No.: 5
SCALE:

DRAWING No.
5

Appendix C

Design Calculations and Cost Estimate

Calculate Peak Discharge

Known

Total Drainage Area		7.25	ac	315810	sf
Impervious Area		1.78	ac	77536.8	sf
Pervious Area		5.47		238273.2	sf
% Impervious		25			
Runoff Coefficient		0.27			
Runoff to treat		1	in		
Basin Storage Volume		6500	cf		
HSG		B			
Intensity, I	(Source: NOAA Atlas)				
	2-year	0.141	in/hr		
	10-year	0.218	in/hr		
	100-year	0.340	in/hr		
Depth, P	(Source: NOAA Atlas)				
	WQ event	1.2	in		
	2-year	3.33	in		
	10-year	4.96	in		
	100-year	8.79	in		
Curve Number		61	Open Space, Good condition		
Curve Number		98	Impervious surfaces		
Weighted CN		70			
Surface Storage, S		4.286	in		
Initial Abstration, Ia		0.857	in		
Ia/P					
	WQ event	0.714			
	2-year	0.257			
	10-year	0.173			
	100-year	0.098			
Total Runoff, Qd					
	WQ event	0.025	in		
	2-year	0.905	in		
	10-year	2.007	in		
	100-year	5.150	in		
Release Rate for WQv		0.449	cfs		
Runoff Volume from Bioretention, V					
	WQ event	30.5	cf		
	2-year	1085.7	cf		
	10-year	2408.1	cf		
	100-year	6180.4	cf		
Slope		0.03	ft/ft		
Time of Concentration, Tc	Manning's kinematic equation				
	WQ event	0.690	hr	41.4	min
	2-year	0.414	hr	24.8	min
	10-year	0.339	hr	20.4	min
	100-year	0.255	hr	15.3	min
Unit Peak Discharge					
	WQ event	424	csm/in		
	2-year	532	csm/in		
	10-year	570	csm/in		
	100-year	620	csm/in		

Determine Peak Discharge

Peak Discharge q=(qu)(A)(WQV)			
	WQ event	1.18	cfs
	2-year	1.48	cfs
	10-year	1.59	cfs
	100-year	1.72	cfs

Proposed Pipe Sizing

Determine size of inlet pipe to bioretention (sized to 10-year storm)

Manning's equation Q = (1.486/n)(AR2/3 S1/2)

Q = quantity of storm water runoff (cfs)

n = roughness coefficient (based on wetted perimeter)

A = cross-sectional area of flow (square feet)

R = hydraulic radius (feet)

S = friction slope

Determine size of inlet pipe to bioretention

Design — RCP — D=1.335(n*Q/sqrt(s))^(3/8)

Invert In	Invert Out	Slope	Length (ft)	Mannings n	WQ event (cfs)	Dia (ft)	Dia (in)
300	299.625	0.0150	25	0.013	1.18	0.61	7.4
							Need 8" pipe

Assume inlet pipe flow = oulet pipe flow

Determine size of outlet pipe to PAR2

Design — D=1.335(n*Q/sqrt(s))^(3/8)

Invert In	Invert Out	Slope	Length (ft)	Mannings n	10-year Flow (cfs)	Dia (ft)	Dia (in)
286.83	285.4	0.0151	95	0.013	1.18	0.61	7.3
							Need 8" pipe

Job No.: H172-001
Subject: Hopedale Pond Green Infrastructure Preliminary Cost Estimate
Date: 12/7/2015
Prep. by: BL
Check by: MJR

HOPEDALE POND BIORETENTION CONCEPTUAL ESTIMATE OF QUANTITIES						
Item No.	**Description of Item**	**Units**	**Quantity**	**Unit Price**	**Total**	**Comments**
--	BIORETENTION BASIN	CF	6500	$ 15.00	$ 97,500.00	Water Quality Volume
202	MANHOLE	EA	1	$ 3,500.00	$ 3,500.00	
983.1	RIPRAP	SY	85	$ 65.00	$ 5,525.00	
--	FILTER FABRIC	SY	1600	$ 4.00	$ 6,400.00	Geomembrane liner for bioretention basin
250.08	8 INCH POLYVINYL CHLORIDE SANITARY SEWER PIPE	LF	195	$ 105.00	$ 20,475.00	
268.08	8 INCH PIPE SUBDRAIN	LF	25	$ 29.00	$ 725.00	
269.06	6 INCH SLOT-PERFORATED CORRUGATED PLASTIC PIPE (SUBDRAIN)	LF	850	$ 37.00	$ 31,450.00	
	GRASS FILTER STRIP	LF	25	$ 3.00	$ 75.00	

	Sub-Total:	$ 165,650.00
25%	Contingency:	$ 41,412.50
	Construction Budget Estimate:	$ 207,062.50
	SAY	**$ 207,000.00**

Appendix D

Quality Assurance Project Plan and Loading Model Calculations

Hopedale Pond Green Infrastructure Design
Quality Assurance Project Plan

Version: 2.1

Date of Version: January 12, 2016

Prepared by:

ESS Group
10 Hemingway Drive
East Providence, RI 02915

Prepared in cooperation with the:

New England Interstate Water Pollution Control Commission, Narragansett Bay Estuary Program and the U.S. Environmental Protection Agency

EPA Grant #CE96184201 and CE96172201

Questions concerning this QAPP should be directed to:

Daniel Iacovelli
Chairman
Town Hall, PO Box 7
Hopedale, Massachusetts 01747
(508) 254-0460
dan_iacovelli@yahoo.com

This project was funded by an agreement awarded by the Environmental Protection Agency to the New England Interstate Water Pollution Control Commission in partnership with the Narragansett Bay Estuary Program. Although the information in this document has been funded wholly or in part by the United States Environmental Protection Agency under agreements CE96184201 and CE96172201 to NEIWPCC, it has not undergone the views of the Agency and no official endorsement should be inferred. The viewpoints expressed here do not necessarily represent those of the Narragansett Bay Estuary Program, NEIWPCC, or EPA, not does mention of trade names, commercial products, or causes constitute endorsement or recommendation of use.

NEIWPCC
New England Interstate Water Pollution Control Commission

NARRAGANSETT BAY ESTUARY PROGRAM

SECTION A: PROJECT MANAGEMENT

A1 Approval Page:

Grant Project Manager: ______________________ 1-15-16
Daniel Iacovelli, Chairman — Date
Town of Hopedale, MA

NEIWPCC QA Manager: ______________________ 1/20/16
Michael Jennings, NEIWPCC — Date
Program Manager

NBEP Project Manager: ______________________ 1/15/16
Heather Radcliffe, NEIWPCC — Date
Program Manager and Staff Attorney

Contractor Project Manager: ______________________ 01/13/16
James Riordan, ESS Group — Date
Principal Scientist

Contractor Lead Modeler: ______________________ 01-13-2016
Brenda Lam, ESS Group — Date
Engineer

Contractor QA Officer: ______________________ 1-13-16
Payson Whitney, ESS Group — Date
Vice President

EPA Project Officer: ______________________ 1/27/16
Caitlyn Whittle, USEPA Region 1 — Date
Project Officer

EPA QA Reviewer: ______________________ 1/28/2016
Nora Conlon, USEPA Region 1 — Date
QA Reviewer

A2 Table of Contents

Tables

Figures

A3 Distribution List

Table A3.1 presents a list of people who will receive the approved QAPP, the QAPP revisions, and amendments as well as their role and project responsibilities.

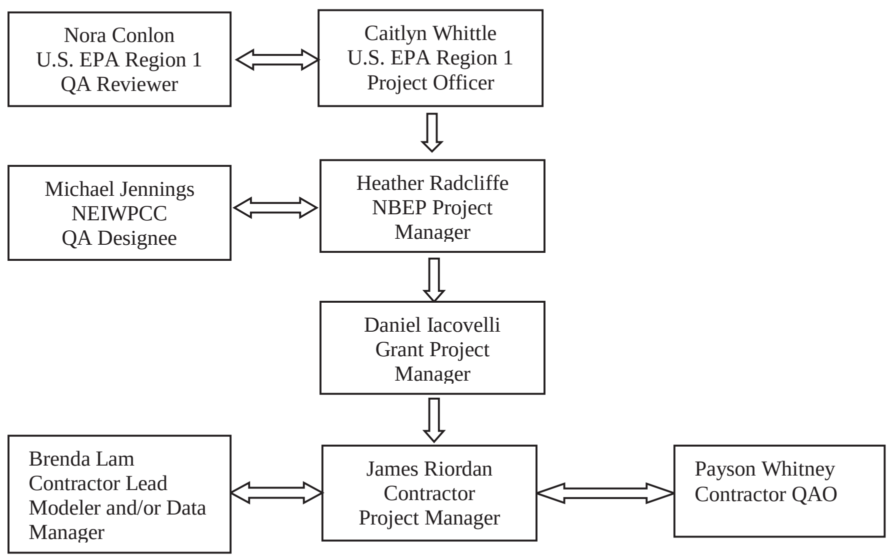
Table A3.1 QAPP Distribution List and Project Roles and Responsibilities

QAPP Recipient and Affiliation	Project Role	Responsibility	Telephone Number and Email
Daniel Iacovelli Town of Hopedale, MA	Grant Project Manager	Oversight and management of the project grant and contractor	(508) 254-0460 dan_iacovelli@yahoo.com
Michael Jennings NEIWPCC	NEIWPCC QA Manager	Management of quality assurance and control for NEIWPCC	(978) 349-2520 mjennings@neiwpcc.org
Heather Radcliffe NEIWPCC	NBEP Project Manager	Management of this NBEP project	(978) 349-2522 hradcliffe@neiwpcc.org
James Riordan ESS Group	Contractor Project Manager	Management and responsibility of the project for ESS Group	(401) 330-1221 jriordan@essgroup.com
Brenda Lam ESS Group	Contractor Lead Modeler	Conduct modeling	(401) 330- 1244 blam@essgroup.com
Payson Whitney ESS Group	Contractor QA Officer	Provide quality assurance and control for ESS Group	(781) 419-7750 pwhitney@essgroup.com
Caitlyn Whittle USEPA Region 1	EPA Project Officer	Administer fiscal and technical aspects of the grant project for EPA	(617) 918-1748 whittle.caitlyn@epa.gov
Nora Conlon USEPA Region 1	EPA QA Reviewer	Management of quality assurance and control for EPA	(617) 918-8335 conlon.nora@epa.gov

A4 Project/Task Organization

The following section provides the names, duties, and responsibilities of key project participants as well as an organizational chart.

Figure A4.1. Organization Chart - Lines of Communication



Town of Hopedale, Massachusetts
Hopedale applied for and received federal grant funds from New England Interstate Water Pollution Control Commission (NEIWPCC) to assist in conducting this project. Hopedale will oversee project work related to construction and subcontracting. Hopedale is working in partnership with ESS Group and will oversee ESS's work and deliverables as they relate to the grant.

NEIWPCC
NEIWPCC was the grantor of grant monies being used for this project to the Town of Hopedale. NEIWPCC will administer fiscal and technical aspects of the grant project as they relate to the grant from NEIWPCC to Hopedale.

ESS Group
ESS Group is a partner with the Town of Hopedale and will provide technical services including modeling, water quality science and engineering for this project. James Riordan, ESS Project Manager, will be responsible for maintaining and distributing the official approved QAPP.

USEPA Region 1
EPA was the initial grantor to NEIWPCC/Narragansett Bay Estuary Program (NBEP) for grant monies that are being used for this project. USEPA Region 1 will administer fiscal and technical aspects of the grant project as they relate to the grant from EPA to NEIWPCC.

A5 Problem Definition/Background

The purpose of the QAPP is to clearly delineate the quality assurance policy, management structure and procedures to implement the requirements necessary to verify, calibrate, and validate the output of the modeling process associated with this project. This QAPP is reviewed by the NEIWPCC and EPA to help ensure that the outputs and data generated for the purposes described within are scientifically valid and legally defensible. This process will facilitate the use of project outputs and data by the NBEP and other programs deemed appropriate by the NEIWPCC and EPA.

The overall goal of this project is to improve water quality related to bacteria and nutrients in Hopedale Pond advancing design of bioretention to approximately 50% for subcatchment C of the Dutcher Street Outfall Catchment. Hopedale Beach has been out of active use for several years and does not currently support swimming due high levels of pathogens. The primary source of bacteria to Hopedale Pond was identified as part of the Diagnostic and Feasibility Study for Hopedale Pond (ESS, 2009) as the Dutcher Street Outfall, which was found to contribute up to 200,000 cfu/100 ml and phosphorus in the range of 0.2 – 0.3 mg/L, in part from wet weather. These levels of pollutants were confirmed in a 2014 sampling study. The Parks Commission is spearheading an effort to improve water quality and reestablish primary-contact recreation using green infrastructure retrofits as well as illicit discharge elimination.

A6 Project/Task Description and schedule

The table below summarizes the tasks, deliverables, and timeline for the stormwater BMP modeling scope of work. The text following the table provides a narrative description of the scope of work. A map of the geographic location to be studied is also provided and will include the drainage area of the Dutcher Street Outfall, which discharges to Hopedale Pond.

Table A6.1 Project Schedule and Timeline

Task	Deliverable	Timeline
Develop Quality Assurance Project Plan (QAPP)	Approved QAPP	October 2015 – January 2016
Measure and Document Results	Water Quality Modeling for six BMP Designs[a]	January 2016 - March 2016
Final Reports	Final Report	May 2016
QAPP Expiration Date		January 31, 2017

Notes:

a. Locations and types of BMPs will include bioretention following the definition of BMPs listed in Table H-3 of the *Rhode Island Stormwater Design and Installation Standards Manual*, which is provided as part of Appendix A to this QAPP. The Simple Method from the Rhode Island Stormwater Manual will be used for modeling. The Simple Method has been selected as it has been accepted previously under a quality assurance project plan. Rainfall values will be updated for use in Hopedale. Pollutant reduction values will be taken from the *Massachusetts Stormwater Handbook* as it represents the technical regulatory standard in Massachusetts. The *Massachusetts Stormwater Handbook* presents a method for modeling TSS, but does not include modeling for nutrients or pathogens.

Develop a QAPP: The overall grant project includes modeling and, therefore, involves environmental data operations. The NEIWPCC Quality Management Plan requires that quality assurance project plans are developed and approved for all projects involving environmental data operations (i.e., collection, analysis, and/or manipulation of environmental data). The timeline in Table A6.1 assumes 60 days for the development of the QAPP and 90 days for the review and approval of the QAPP by NEIWPCC and U.S. EPA QA officers and up to 60 days to complete revisions that may be needed for approval.

Measure and Document Results: We will estimate water quality benefits for nutrient and pathogen load reduction using the Simple Method as defined in the 2015 *Rhode Island Stormwater Design and Installation Manual*. (See Appendix A,[1] which provides a detailed description of the method to be used.)

The Simple Method was selected for this project because it can efficiently simulate pollutant loadings of nutrients, TSS, and pathogens associated with stormwater runoff. The Simple Method also provides the ability to model pollutant removals associated with best management practices in urbanized settings and to develop relative cost-benefit analysis of BMPs using an Excel spreadsheet. This method was previously accepted by NEIWPCC and EPA as part of QAPP that was developed for a similar project for West Warwick, Rhode Island. For the project described in this QAPP, the conceptual BMP design at Hopedale Park will be update to approximately 50% completion. A cost opinion will be developed based on the updated design using standard engineering costing methods.

[1] Although Appendix A addresses a number of pollutants, estimation of water quality benefits will be limited to bacteria and phosphorus.

Final Reporting: We will develop a project final grant report in accordance with NEIWPCC grant guidance, which will include the modeling results and a description of QAPP process.

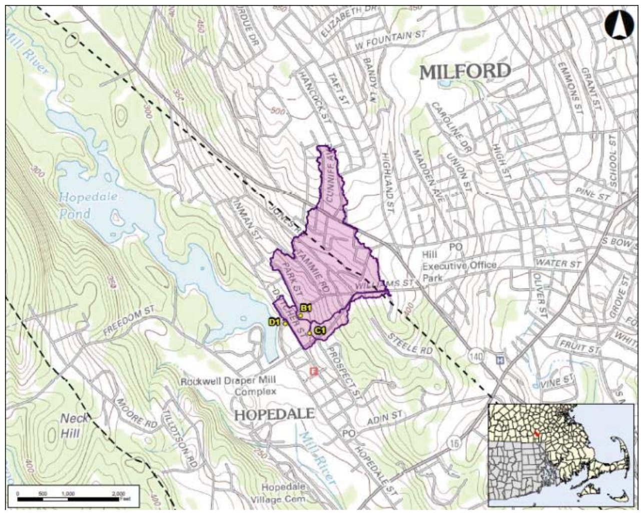


Figure A6.1 Geographic Location to be Studied (which will include the whole town)

A7 QUALITY OBJECTIVES AND CRITERIA FOR MODEL INPUTS/OUTPUTS

The modeling procedure focuses on estimating relative pathogen and nutrient contributions from the Hopedale area of the Hopedale Pond Watershed and on modeling green infrastructure BMPs that could result in substantial and cost-effective pathogen and nutrient load reduction. Substantial and cost-effective pathogen and nutrient load reduction, for purposes of this project, means BMPs that are anticipated to have a pathogen-removal efficiency of 90% of bacteria and 50% of phosphorus or more from approximately 70,000 – 80,000 square feet of contributing impervious surface.

We will run the model for the 1.2-inch, Type III, 24-hour wet-weather event, which is anticipated to generate one inch of runoff using the predictive methods of the Natural Resource Conservation Service's *Urban Hydrology for Small Watersheds* (TR-55). This is also known as the water quality event since it is the statistical 24-hour storm that generates runoff equal to the water quality volume. The primary goal of the model is to evaluate the relative cost effectiveness of various BMPs in reducing pollutant loads while targeting specific pollutant sources. Appendix A provides a thorough description of the modeling approach, data to be used and parameters. Generally speaking, input and output data include the parameters listed in Table A7.1.

Table A7.1 Simple Method Model Input and Output Data

Input	Data Source	Data Range	Output
Annual Rainfall (inches/year)	Figure H-8, RISWM[a]	45 – 47 inches/year[b]	Total bacteria and phosphorus pre and post implementation (trillion colonies/year and lbs/year, respectively)
Mean Pollutant Contributions in Runoff (mg/l)	Table H-2, RISWM	1.74 – 2.1 mg/l	
Impervious Area (acres)	RIGIS Impervious Surface Coverage	Commonly 1 – 50 acres	
Drainage Area (acres)	LiDAR and topographic contours	Commonly 5 – 100 acres	
Percent Impervious	Calculated (divide impervious area by drainage area)	10 – 70%	
Pollutant Removal Rate of BMPs[c]	Table H-3, RISWM	30% – 65%	

Notes:

a. "RISWM" means the 2015 *Rhode Island Stormwater Design and Installation Standards Manual*.
b. The Simple Method Model is run on annual rainfall data as provided in the RISWM. Rainfall values will be updated for Hopedale, MA, using values in the Massachusetts Stormwater Manual. Since the purpose of the modeling for this project is to determine the relative effectiveness of BMPs for cost-benefit, updating the annual rainfall will not substantively affect outcome.
c. Bioretention was previously selected as the BMP to be designed and is the only BMP being modeled.

A8 Special Training Requirements/Certification

This modeling effort requires proficient knowledge, experience and understanding of the pollutant loading /land use interactions and receiving-water-response dynamics to nitrogen inputs. The scientists overseeing the modeling calculations and the related water quality interpretations of findings are experienced senior level scientists having 20 or more years of experience in surface water impact analysis, pollutant loading and water quality investigations. The appropriate user guides and manuals provided with the models described in Section A6 will be used to guide the modeling process.

A9 Documentation and Records

The modeling methods, assumptions and results will be presented in the final report for this project (anticipated to be completed by May 2016). Results will be presented in a tabular format as generated by use of an Excel spreadsheet with modeling algorithms. Upon conclusion of the project, NEIWPCC will retain its project files for three years following the close of the EPA funding agreement supporting the project. Spreadsheets and final report will be kept by ESS Group as part of the project files for three years. ESS Group electronic documents are backed up on a daily basis. The ESS Group Project Manager, James Riordan, will be responsible for maintenance and distribution of the approved QAPP and updates to it. These will be provided electronically as needed. No other modeling documents are anticipated.

SECTION B: MEASUREMENT AND DATA ACQUISITION

This QAPP is for modeling. In accordance with Appendix C, "Checklist for QA Project Plan Elements for Modeling" of the NEIWPCC *Guide for Development and Approval of QA Project Plans*, subsections B1 – B6 and B8 do not need to be addressed. Therefore, Section B of this QAPP includes only subsections B7, B9, and B10.

B7 Model Calibration

Calibration for the study area will be completed as part of the initial setup of the model as discussed in Appendix A. Model setup is limited to data input into a spreadsheet of such parameters as annual precipitation, study area land use, and study area size. The Simple Model is not available commercially and formulae to run the model will need to be entered manually. We will confirm that the model is working by running the example data provided in Appendix A. The model will be run on a personal computer with Excel spreadsheet software. Initiating and running the model will require no other special tools, instruments, or certified equipment.

It is recognized that the algorithms used to develop this model are relatively simplistic and provide a somewhat limited representation of actual loading and reduction. However, the purpose of the model is to select cost-beneficial BMPs and is, therefore, appropriate for the proposed project.

B9 Non-Direct Measurements (Data Acquisition Requirements)

This project will use a variety of non-direct (i.e., secondary) data and measurements including: GIS data layers from MassGIS, USGS, the Town of Hopedale, and ESS Group including watershed boundary, land use, soil type, hydrology, roads, drainage layers, topography, LiDAR, and orthophotos. GIS products will adhere to the EPA's National Geospatial Data Policy and NEIWPCC's contractual requirements for this project. Data collected during this project will be used to determine effectiveness of BMP designs, prioritize sites for future BMP implementation and used for comparison with future water quality monitoring efforts. Table B9.1 lists the datasets that are planned to be used and key features regarding their quality. If additional datasets are used a decision tree will be used to confirm their quality. See Appendix B for a copy of the data quality decision tree. If this project uses any data whose quality cannot be determined, the use of that data will be discussed (along with the rationale for inclusion and implications for the project conclusions) in the project final report.

Table B9.1 Datasets and Quality Features

GIS Data Layer	Origin	Collection Source	Year Published	Resolution	Geographic Coverage	Collected Under a QAPP
Land Use	MassGIS,[a] and Sanborn[b]	MassGIS[c]	2005	0.5m	Townwide	Unknown
Soil Type	USDA/NRCS[d]	MassGIS	2012	1:5,000	Townwide	Unknown
Hydrology	USGS[d]	MassGIS	2003	1:5,000	Townwide	Unknown
Roads	MassDOT[e]	MassGIS	2014	1:5,000	Townwide	Unknown
Topography	USGS	MassGIS	2011	1:5,000	Townwide	Unknown
LiDAR	Various	MassGIS	2014	1m GSD	Townwide	Unknown
Orthophotos	USGS	MassGIS	2014	0.3m	Townwide	Unknown
Impervious Surface	Sanborn	MassGIS	2005	1m	Townwide	Unknown
Pollutant Concentrations for Land Use	Various	RISWM[f] (Table H-2)	Various	N/A[g]	N/A	Unknown
Annual Rainfall Depth	NOAA	NOAA	2015	Unknown	Townwide	Unknown
BMP Pollutant Removal Efficiency[h]	Various	RISWM (Table H-3)	Various	N/A	N/A	Unknown

Notes:

a. "MassGIS" means Massachusetts Geographic Information Systems.
b. "Sanborn" means The Sanborn Map Company, Inc.
c. "USDA/NRCS" means US Department of Agriculture, Natural Resources Conservation Service.
d. "USGS" means US Geological Survey
e. "MassDOT" means Massachusetts Department of Transportation.
f. "RISWM" means the 2015 *Rhode Island Stormwater Design and Installation Standards Manual*.
g. "N/A" means not applicable.
h. Bioretention was previously selected as the BMP to be designed and is the only BMP being modeled.
i. Source of metadata: http://www.mass.gov/anf/research-and-tech/it-serv-and-support/application-serv/office-of-geographic-information-massgis/datalayers.

B10 Data Management and Hardware/Software Configuration

Data collected by the Contractor Lead Modeler and used in the modeling process will be documented in the final report. Data will be kept by ESS Group as computer files for three years and will be available to the Town of Hopedale, NEIWPCC, and USEPA upon request. ESS will store the data on its computer network in the format that it is in when it is collected. Files on the network are stored by project, exclusively, under a folder named by the project number and project name. Data collected will be stored in the "resources" subfolder of the project folder.

Some revisions to delineation of drainage basins or other BMP engineering calculations may be done as part of this project using GIS. ESS Group will use Esri ArcGIS version 10.3 to do GIS analysis. GIS analysis may be needed to adjust calculations (e.g., watershed delineation, water quality volume, etc.) that were made during conceptual design in the second phase stormwater utility planning. Conceptual design was previously completed by the Town and is not included as part of the scope of work that is subject to this QAPP.

SECTION C: ASSESSMENT AND OVERSIGHT

C1 Assessments and Response Actions

Modeling runs will be reviewed by the project team's Project Manager for quality assurance regarding the model input and output and particularly to ensure that the model output reasonably reflects existing conditions or the expected results in evaluating various BMP measures. The Contractor Lead Modeler will be responsible for data entry. The Project Manager will review the data entry and computations, by checking each data cell. Table A7.1 (above) indicates expected data ranges. The Project Manager will use a calculator to manually check the accuracy of computed data. Final model summary sheets will be reviewed by the project QAO prior to distribution to the QAPP project team.

NEIWPCC may implement, at their discretion, various audits or reviews of this project to assess conformance and compliance to the quality assurance project plan in accordance with the NEIWPCC Quality Management Plan.

The Project Manager will consult with the QA Manager to include a description of QA activities, any QA issues noted, and corrective actions taken in quarterly reports, to be reviewed by the NEIWPCC Program Manager.

C2 Reports to Management

The project status and preliminary results will be presented as part of quarterly reporting, which will be developed by ESS Group and the Town. These reports will be provided to the NBEP Project Manager. In accordance with NEIWPCC Quarterly Report Guidance (http://www.neiwpcc.org/contractors/guidance.asp):

> The quarterly reports shall describe work progress to date; completed outputs; problems encountered and anticipated, including but not limited to the means of responding to those problems; a statement of activity anticipated during the next reporting period; and a comparison of the percentage of the Project completed to the project schedule.

The reports will address modeling progress under "task list and status."

The Town previously selected BMP alternatives using cost-benefit of annual total nitrogen reduction as a selection factor. BMPs were designed at the conceptual level with unit-based construction costs. For the project described in this QAPP, the selected BMP design will be update to approximately 50% completion. A cost opinion will be developed based on the updated design using standard engineering costing methods. Modeling results will be presented in a tabular summary as percent and mass reduction of annual total nitrogen load for selected alternatives by drainage area and in aggregate for the study area. The tabular summary will also include cost-benefit expressed as dollars per pound of total nitrogen reduced per year using cost of BMP construction (applied over a single year) as the cost basis.

Baseline and preliminary modeling results will be presented in April 2016 (or as part of the quarterly report following QAPP approval). If corrective actions are needed they will be addressed as part of the Final Project Plan. If uncertainties arise in the input or output data that might significantly affect project decisions, a review and evaluation will be made by the Town, in consultation with the key project participants on the distribution list. The Final Project Plan is scheduled for completion in May 2016 and will be posted on the Town's website.

SECTION D: DATA VALIDATION AND USABILITY

D1 Departures from Validation Criteria

The modeling results will be reviewed by the Grant Project Manager, NBEP Project Manager, Contractor Project Manager as well as the QA Officer for completeness and reasonableness based on best professional judgment and review of spreadsheet calculations.

D2 Validation Methods

As described above in section C1, modeling runs will be reviewed by the project team's Project Manager for quality assurance regarding the model input and output and particularly to ensure that the model output reasonably reflects existing conditions or the expected results in evaluating various BMP measures. As described in B7, we will confirm that the model is working by running the example data provided in Appendix A of this QAPP. The model will be run on a personal computer with Excel spreadsheet software. There is no anticipated need for data validation software for this project.

Final model summary sheets will be reviewed by ESS Group's QAO and provided as part of the final project report. The ESS Group Project Manager, James Riordan, will be responsible for distribution of the report electronically to the distribution list. If the model predictions indicate that the various BMPs tested, or combinations thereof, will not result in load reductions sufficient enough to cause the desired reduction in nitrogen, then the Town, NEIWPCC and EPA project managers will be notified of the results and a meeting will be scheduled to review the model assumptions, approach and results.

D3 Reconciliation with User Requirements

The quarterly reports will be the mechanism by which data users will be able to have input on the results. In compiling the reports, ESS Group will assess anomalies or departures from assumptions. The modeling design is quite simple. Departures from assumptions about contaminant concentrations in effluent would be difficult to determine, as there is little equivalent information available for comparison. The eventual use of the data as baseline information for the potential decrease in nutrient loading to estuarine waters by stormwater will be discussed in the final report.

Appendix A
Rhode Island Stormwater Design and Installation Standards Manual
Pollutant Loading Analysis (Simple Method)

H.3 POLLUTANT LOADING ANALYSES

H.3.1 Introduction

On a case by case basis, the permitting agency may require applicants to document that a particular project does not unduly contribute to, or cause, water resource degradation (generally for sensitive resource areas or where an elevated concern for water quality exists) or to document a reduction in pollutant load (generally, as a consequence of a TMDL requirement). In these cases, applicants may be required to calculate potential stormwater pollutant loadings for projects for pre-development and post-development conditions.

When such an analysis is required of the applicant, the Simple Method (Schueler, 1987) can be used to demonstrate urban stormwater pollutant loadings. The Simple Method requires estimates of annual rainfall, site percent impervious cover, land use type, and pollutant loading coefficients based on land use.

For a more detailed description of this method refer to Controlling Urban Runoff: A practical manual for planning and designing urban BMPs (Schueler, 1987). Table H-2 provides event mean concentrations (EMCs) in milligrams per liter (mg/L) for typical pollutants of concern associated with stormwater runoff (# col/100ml for bacteria). There may be an interest in calculating the loading rates of other pollutants not listed in this table. If this is necessary, an applicant shall use EMC data from a reliable source, as approved by the permitting agency, based on the land use category. These EMCs must be documented by scientific studies and referenced by the applicant.

The method outlined in this section is most often applied to calculating loadings to surface water bodies. Other pollutant loading methods may be acceptable, provided the applicant submits the methodology and data used along with the reasoning for the chosen method. All information supplied by the applicant will be reviewed by the permitting agency to determine the relevance of the model to the situation.

H.3.2 Overview of the Simple Method

Stormwater pollutant export load (L, in pounds or billion colonies) from a development site can be determined by solving the following equation:

(Eq 1.) $$L = [(P)(Pj)(Rv)/12](C)(A)(2.72)$$

Where:

- P = rainfall depth (inches)
- Pj = rainfall correction factor
- Rv = runoff coefficient expressing the fraction of rainfall converted to runoff
- C = flow-weighted mean concentration of the pollutant in urban runoff (mg/L)
- A = contributing drainage area of development site (acres)
- 12, and 2.72 are unit conversion factors

For bacteria, the conversion factor is modified, so the loading equation is:

(Eq 1a.) $L = 1.03(10^{-3})[(P)(Pj)(Rv)](C')(A)$

Where:

- P = rainfall depth (inches)
- Pj = rainfall correction factor
- Rv = runoff coefficient expressing the fraction of rainfall converted to runoff
- C' = flow-weighted mean bacteria concentration (#col/100 ml)
- A = contributing drainage area of development site (acres)
- 1.03 is a unit conversion factor

Table H-2 Median EMC Values for Differing Land Use Categories

Pollutant (mg/l)	Land Use Category				
	Residential	Commercial	Industrial	Highways	Undeveloped/Rural[3]
TSS	100[1]	75[1]	120[1]	150[1]	51
TP	0.3	0.2	0.25	0.25	0.11
TN	2.1	2.1	2.1	2.3	1.74
Cu	.005	.096	.002	.001	-
Pb	.012	.018	.026	.035	-
Zn	.073	.059	.112	.051	-
BOD	9.0	11.0	9.0	8.0	3.0
COD	54.5	58.0	58.6	100.0	27.0
Bacteria*	7000	4600	2400	1700	300

Sources:

1 Caraco (2001); default values from Watershed Treatment Model, from several individual assessments

2 (shaded) Maestre and Pitt (2005); National Stormwater Quality Database, v 1.1

3 CDM (2004) Merrimack River Watershed Assessment Study, Screening Level Model

* Bacteria concentration in #col/100 ml.

P (depth of rainfall)

The value of P selected depends on the time interval over which loading estimates are necessary (usually annual rainfall – See Figure H-8).

Appropriate annual rainfall values for a site specific location can be interpolated from Figure H-8 or obtained from the Northeast Regional Climate Center. If a load estimate is desired for a specific design storm (e.g., 10-year 24-hour, Type III storm), the user can supply the relevant value of P derived from Table 3-1. Caution is required as EMCs vary as a function of rainfall amount and intensity and those presented in Table H-2 are median values from a range of storms more representative of long-term loading. If a load is desired from a larger storm such as the 10-year, 24 hour, Type III storm, applicants shall provide appropriate documentation of the source of the EMC used. All rainfall data used in the analysis must be applicable to site location and referenced for review.

<u>Pj (correction factor)</u>
Use a value of 0.9 for Pj. This represents the percentage of annual rainfall that produces runoff. When solving the equation for individual storms, a value of 1.0 should be used for Pj.

<u>Rv (runoff coefficient)</u>
Rv is the measure of site response to rainfall events and is calculated as:

(Eq 2.) $Rv = r/p$

Where:
r = storm runoff (inches)
p = storm rainfall (inches)

The Rv for a site depends on soil type, topography, and vegetative cover. However, for annual pollutant loading assessments, the primary influence on Rv is the degree of watershed imperviousness. The following equation has been empirically derived from the Nationwide Urban Runoff Program studies (USEPA, 1983) and is used to establish a value for Rv.

(Eq 3.) $Rv = 0.05 + 0.009(\%I)$

Where:
%I = the percent of site imperviousness

A value for I can be calculated by summing the areas of all impervious surfaces (e.g., buildings, driveways, roads, parking lots, sidewalks, etc.) and dividing this area by the total contributing drainage area. If more than one land use is present at the site, divide the impervious portion of each land use by its respective total area.

<u>A (drainage area)</u>
The total contributing drainage area (acres) can be obtained from site plans.

<u>C (pollutant concentration)</u>
Choose the appropriate value of C from Table H-2.

<u>*Sample calculations:*</u>

A 30-acre undeveloped parcel is to be developed into a residential subdivision with the remaining 10 acres converted to a commercial plaza. Assume the commercial land use area has impervious surfaces covering 85% of the area, while the residential subdivision has 35% impervious surfaces. Also assume the entire 30-acre site has all drainage directed to one outlet (into a coastal pond). This site is located in an area that receives approximately 45 inches of precipitation per year, say Providence. What would be the potential annual loading rate of total nitrogen (TN) to the coastal salt pond from this site without the installation of onsite BMPs; compare pre- and post-development scenarios.

Pre-development conditions

Undeveloped site: (Eq.3) Rv = 0.05 + 0.009(%I) = 0.05 + 0.009(0) = 0.05

(Eq.1) L = [(P)(Pj)(Rv)/(12)](C)(A)(2.72); from Table H-2, C = 1.74 mg/l

L = [(45)(0.9)(0.05)/12](1.74)(30)2.72 = ***24.0 lbs TN/year***

Post-development conditions

Residential: (Eq.3) Rv = 0.05 + 0.009(%I) = 0.05 + 0.009(35) = 0.365

(Eq.1) L = [(P)(Pj)(Rv)/(12)](C)(A)(2.72); from Table H-2, C = 2.1 mg/l

L = [(45)(0.9)(0.365)/12](2.1)(20)2.72 = ***140.7 lbs TN/year***

Commercial: (Eq.3) Rv = 0.05 + 0.009(%I) = 0.05 + 0.009(85) = 0.815

(Eq. 1) L = [(P)(Pj)(Rv)/(12)](C)(A)(2.72); from Table H-2, C = 2.1 mg/l

L = [(45)(0.9)(0.815)/12](2.1)(10)2.72 = ***157.1 lbs TN/year***

Total annual nitrogen loading from the developed site = 140.7 + 157.1 = ***297.8 lbs TN/year***

Conclusion: Development of the site results in a net increase of 273.8 lbs of nitrogen (297.8 – 24.0) into the coastal salt pond per year.

Now evaluate the same example except for Bacteria:

Pre-development conditions

Undeveloped site: (Eq.3) Rv = 0.05 + 0.009(%I) = 0.05 + 0.009(0) = 0.05

(Eq 1a.) L = 1.03(10^{-3})[(P)(Pj)(Rv)](C')(A)); from Table H-2, C' = 300 col/100 ml

L = [1.03(10^{-3})(45)(0.9)(0.05)](300)(30) = ***18.8 Billion Colonies/year***

Post-development conditions

Residential: (Eq.3) Rv = 0.05 + 0.009(%I) = 0.05 + 0.009(35) = 0.365

(Eq 1a.) L = 1.03(10^{-3})[(P)(Pj)(Rv)](C')(A)); from Table H-2, C' = 7,000 col/100 ml

L = [1.03(10^{-3})(45)(0.9)(0.365)](7,000)(20) = ***2,131.6 Billion Colonies/year***

Commercial: (Eq.3) Rv = 0.05 + 0.009(%I) = 0.05 + 0.009(85) = 0.815

(Eq 1a.) L = 1.03(10^{-3})[(P)(Pj)(Rv)](C')(A)); from Table H-2, C' = 4,600 col/100 ml

L = [1.03(10^{-3})(45)(0.9)(0.815)](4,600)(10) = ***1,563.9 Billion Colonies/year***

Total annual bacteria loading from the developed site = 2,131.6 + 1563.9 = ***3,695.5 Billion Colonies/year***

Conclusion: Development of the site results in a net increase of ***3,676.7 Billion Colonies/year*** *(3695.5 – 18.8) into the coastal salt pond per year.*

Applicants will frequently need to evaluate the potential pollutant removal effectiveness of stormwater practices when conducting a pollutant loading analysis. To do this, applicants can use the rated pollutant removal effectiveness as listed in Tables H-3 and H-4 as a basis of estimating pollutant removal. These values have been derived from a variety of sources based on actual monitoring data and modified, where appropriate, to reflect the specific design and sizing criteria contained in Chapters Five, Six, and Seven.

In some cases, the pollutant removal rating values use median values from prior monitoring studies when the studies included a significant number of facilities of similar design criteria as those required in this manual. In other cases, the 75th quartile values (or high end) are reported where it is recognized that the prior monitoring was of insufficient sample size or was of practices with design criteria not as robust as those required in this manual. Lastly, in many cases, there is insufficient prior monitoring of practices for some or all of the reported pollutants, but primary pollutant removal mechanisms are similar to other practices; thus, a removal value is assigned, based on general literature values and/or as a policy decision. In addition, most of the design criteria for water quality BMPs incorporate pre-treatment requirements, such as the requirement for a forebay or grass channel prior to infiltration. In these cases, the rated removal efficiency of the practice is for the total system. For example, the gravel WVTS has a rated TSS removal of 86%; this accounts for the TSS removal of both the required forebay and the gravel bed/permanent pool.

In general, where pollutant loading assessments are requested, applicants may use the rated removal values as a basis for estimating pollutant load. However, other pollutant removal estimates may be acceptable, provided the applicant submits the source of these estimates and data used. All information supplied by the applicant will be reviewed by the permitting agency to determine the relevance of the removal estimates to the situation.

Table H-3 Pollutant Removal Efficiency Rating Values for Water Quality BMPs

Water Quality BMPs (those meeting Min. Std 3)		Median Pollutant Removal Efficiency (%)			
		TSS	TP	TN	Bacteria
WVTS	Shallow WVTS	85%[2]	48%[3]	30%[2]	60%[2]
	Gravel WVTS	86%[3]	53%[1]	55%[3]	85%[2]
Infiltration Practices	Infiltration Basin	90%[2]	65%[3]	65%[2]	95%[2]
	Infiltration Trench	90%[2]	65%[3]	65%[2]	95%[2]
	Subsurface Chambers	90%[2]	55%[2]	40%[2]	90%[2]
	Dry Well	90%[2]	55%[2]	40%[2]	90%[2]
	Permeable Paving	90%[1]	40%[1]	40%[2]	95%[2]
Filters	Sand Filter	86%[3]	59%[3]	32%[3]	70%[2]
	Organic Filter	90%[2]	65%[2]	50%[2]	70%[2]
	Bioretention	90%[1]	30%[2]	55%[2]	70%[2]
	Tree Filter	90%[1]	30%[2]	55%[2]	70%[2]
Green Roofs	Extensive	90%[4]	30%[4]	55%[4]	70%[4]
	Intensive	90%[4]	30%[4]	55%[4]	70%[4]
Open Channels	Dry Swale	90%[1]	30%[2]	55%[2]	70%[2,6]
	Wet Swale	85%[3]	48%[3]	30%[2]	60%[2]

Table H-4 BMP Pollutant Removal Rating Values for Other BMPs

Other BMPs		Median Pollutant Removal Efficiency (%)			
		TSS	TP	TN	Bacteria
Pretreatment BMPs	Grass Channel	70%[1,2]	24%[3]	40%[2]	NT
	Sediment Forebay	25%[4]	8%[5]	3%[5]	12%[5]
	Filter Strip	25%[4]	ND	ND	ND
	Deep Sump Catch Basin	25%[4]	NT	NT	NT
	Hydrodynamic Device	25%[1]	NT	NT	NT
	Oil and Grit Separator	25%[4]	NT	NT	NT
Storage BMPs	Dry Extended Detention Basin	50%[2]	20%[2]	25%[2]	35%[2]
	Wet Extended Detention Basin	80%[3]	52%[3]	31%[3]	70%[3]
	Underground Storage Vault[2]	20%[2]	15%[2]	5%[2]	25%[2]

"ND" Specifies No Data
"NT" Specifies No Treatment
References
1 (UNHSC, 2007b)
2 (CWP, 2007)
3 (Fraley-McNeal, et al., 2007)
4 (prescribed value based on general literature values and/or policy decision)
5 (50% of reported values of low end for extended detention basins)
6 Presumed equivalent to bioretention; will require diligent pollutant source control to manage pet wastes in residential areas

Estimating Pollutant Removal of BMPs

Using the rated efficiencies from Tables H-3 and H-4, applicants can reduce post-development loadings to receiving waters when BMPs are designed, installed, and maintained in accordance with the provisions of this manual.

Example Calculation

The 10-acre commercial project (annual TN load = 157.1 #) is designed to be managed by a gravel WVTS.

The load reduced by the BMP is: 157.1 (.55) = 86.4 lbs TN/year.

*The net loading to the bay is: 157.1 – 86.4 = **70.7 lbs TN/year**.*

Estimating Pollutant Removal of BMPs in Series

In some cases, applicants may have one or more BMPs installed in a series as a so-called "treatment train." In these cases, available research has shown that the pollutant removal efficiency of specific BMPs, for specific pollutants, is reduced for subsequent BMPs in the treatment train arrangement. As stormwater migrates through the treatment train, coarser-grained particles are preferentially removed by the prior BMP, leaving progressively finer particles for practices down the line. The result is that for pollutants associated with fine particulates, removal efficiency drops off significantly (e.g., TSS and TP, in particular).

To account for this phenomenon, a widely applied and generally accepted method has been to discount the rated removal efficiency of the second BMP by a factor of between 75% and 50%, with subsequent BMPs being reduced accordingly (see ARC, 2001).

The Georgia Manual Method applies BMP removals as follows:

- 100% of the rated TSS removal efficiency (E_{TSS}) to the first BMP
    - If E_{TSS} > 80% for the first BMP; E for the second BMP = 50% (regardless of the pollutant constituent).
    - IF E_{TSS} <80% for the first BMP; E for the second BMP = 75% (regardless of the pollutant constituent).
- For succeeding BMPs, E is applied at either 50% or 75% depending on the equivalent E_{TSS} for the preceding BMPs (regardless of the pollutant constituent).

This method does not apply to bacteria, where removal is more a function of die-off than settling/attenuation; thus, the full efficiency is applied to subsequent BMPs.

Example Calculation

Using the example from above, the 10-acre commercial site first drains through a grass channel (designed in accordance with the guidance in Chapter Six) prior to a gravel WVTS (designed in accordance with the guidance in Chapter Five).

Removal efficiencies:
Grass channel: E_{TSS} = 70%; E_{TN} = 40%
Gravel WVTS: E_{TSS} = 86%; E_{TN} = 55%

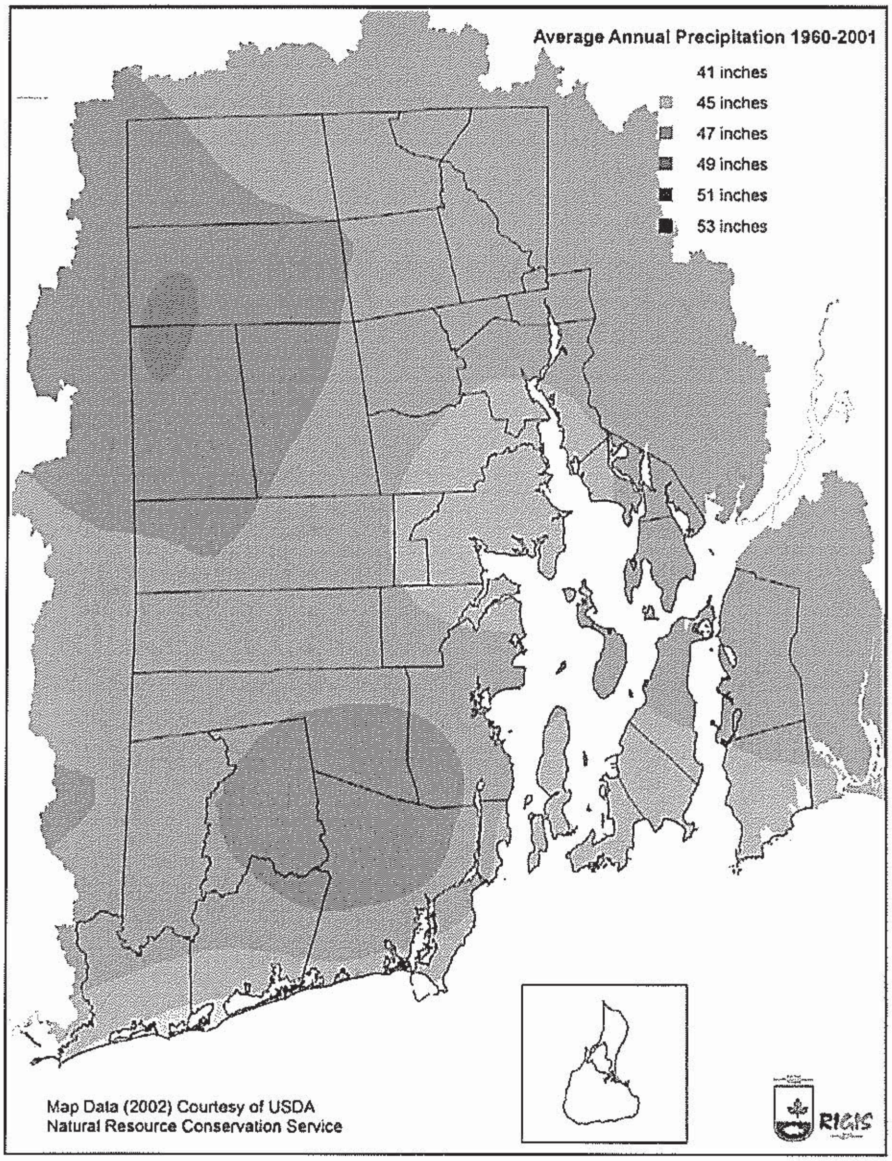
Since treatment train goes from grass channel to gravel WVTS, and E_{TSS} is <80% for the grass channel, reduce the rated TN removal of the second BMP by 25% (E_{TN} = 75% of the rated value). The new net loading reduction can be calculated:

Load reduced by grass channel: 157.1 (.40) = 62.8 lbs/yr;
remaining load = 157.1 – 62.8 = 94.3 lbs TN/year

Load reduced by gravel WVTS: 94.3 [(.75)(.55)] = 38.9 lbs/yr;

The net loading to the bay: 94.3 – 38.9 = ***55.4 lbs TN/year***

Figure H-8 Average Annual Precipitation Values for Rhode Island



H.4 TR-55 "SHORT-CUT" SIZING TECHNIQUE

This section presents a modified version of the TR-55 short-cut sizing approach. The method was modified by Harrington (1987), for applications where the peak discharge is very small compared with the uncontrolled discharge. This often occurs in the 1-year, 24-hour Type III detention sizing.

Using TR-55 guidance (NRCS, 1986), the unit peak discharge (q_u) can be determined based on the curve number and time of concentration. Knowing q_u and T (extended detention time), q_O/q_I (peak outflow discharge/peak inflow discharge) can be estimated from Figure 9.9.

Figure H-10 can also be used to estimate V_s/V_r. When q_O/q_I is <0.1 and off the graph, V_s/V_r can also be calculated using the following equation for Type II/III rainfall distributions:

$$V_s/V_r = 0.682 - 1.43\,(q_O/q_I) + 1.64\,(q_O/q_I)^2 - 0.804\,(q_O/q_I)^3$$

Where: V_s = required storage volume (acre-feet)
V_r = runoff volume (acre-feet)
q_O = peak outflow discharge (cfs)
q_I = peak inflow discharge (cfs)

Figure H-9 Detention Time vs. Discharge Ratios (Source: MDE, 2000)

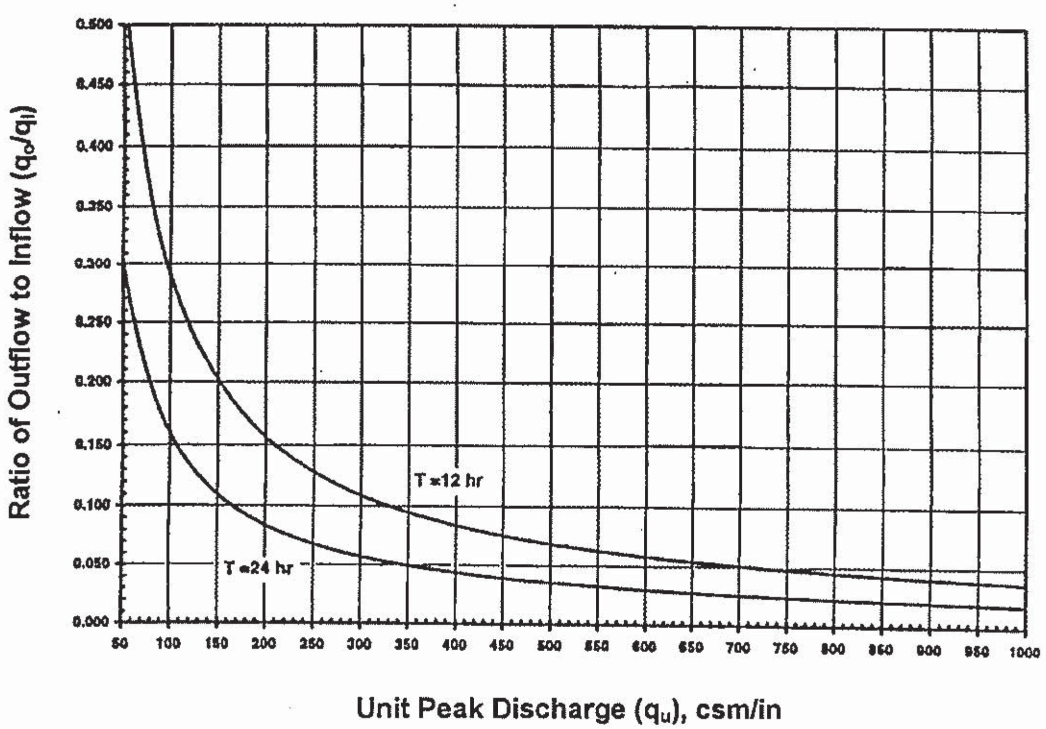
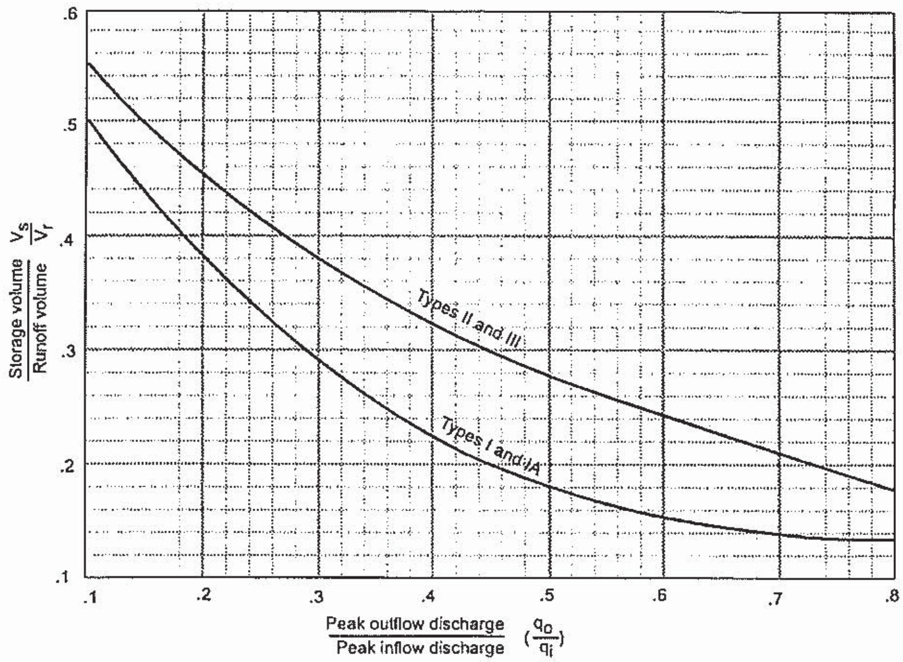


Figure H-10 Approximate Detention Basin Routing For Rainfall Types I, IA, II, and III. (Source: TR-55, 1986)



Example for calculating channel protection volume (CP_v):

For this example, the 1-year runoff from a hypothetical project in Providence County is 1.173 ac-ft = 51,096 ft^3, the composite CN for the project drainage area is 68, and the t_c is 15.1 minutes (0.25 hr).

Thus, the Initial abstraction (I_a) = 0.941, the 1-year precipitation (P) = 3.1"; I_a/P = 0.304.

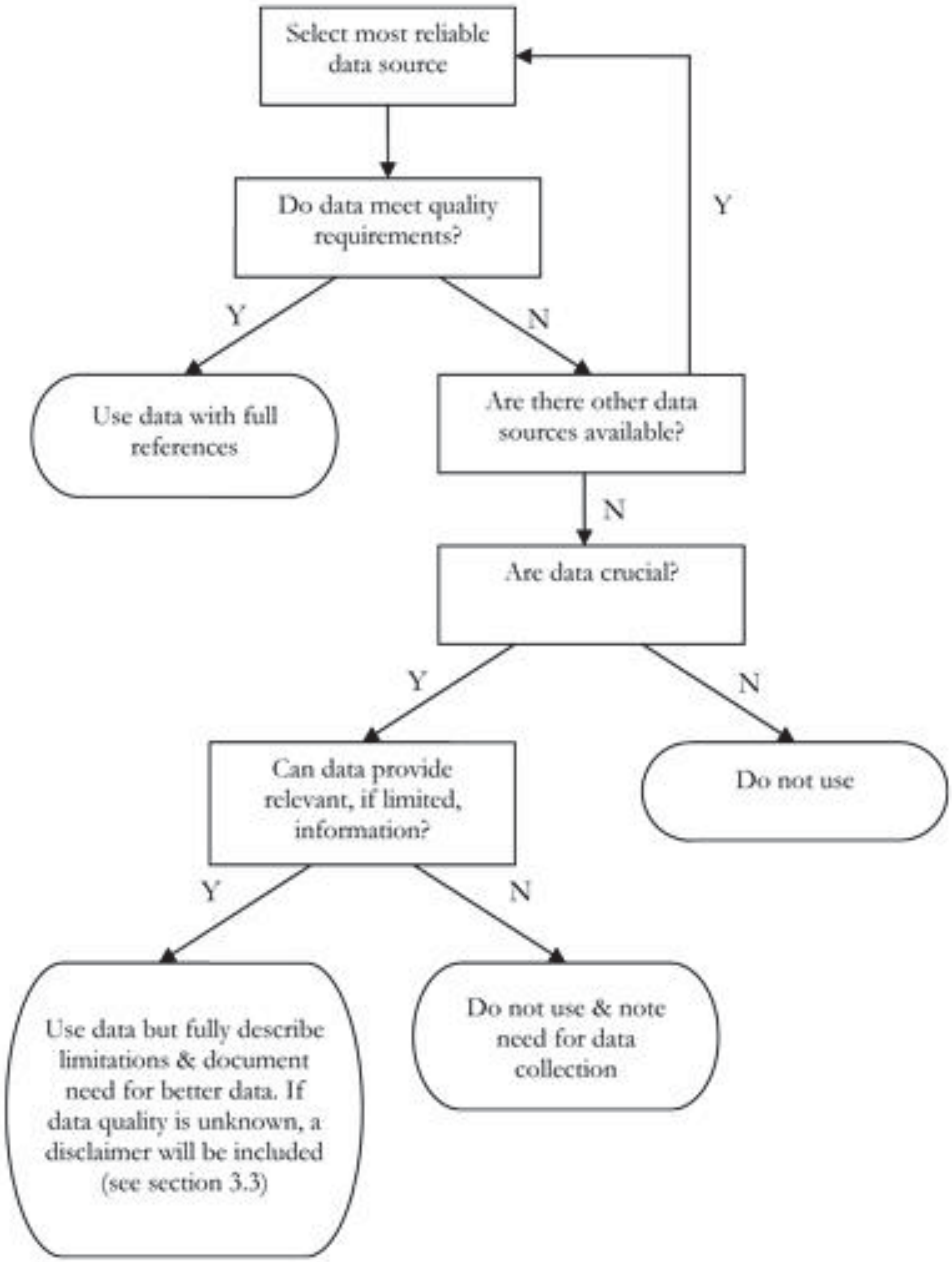
From Exhibit 4-III of NRCS TR-55, read q_u = 450 csm/in (csm = cfs/mi^2). From Figure H-9, for T= 24 hours, read ratio of q_o/q_i = 0.04. Since $q_o/q_i < 0.1$ and off the graph shown in Figure H-10, use the equation provided above to find V_s/V_r where $V_s = CP_v$.

$$CP_v/V_r = 0.682 - 1.43\,(q_o/q_i) + 1.64\,(q_o/q_i)^2 - 0.804\,(q_o/q_i)^3$$
$$CP_v/V_r = 0.682 - 1.43\,(0.04) + 1.64\,(0.04)^2 - 0.804\,(0.04)^3 = 0.627.$$

$$CP_v = 0.627 * V_r = 0.627\,(51{,}096\ ft^3) = \mathbf{32{,}037\ ft^3}$$

Notice that the "short-cut" routing equation from Section 3.3.4 uses a CP_v/V_r = 0.65 and 0.65 > 0.627 that we calculated here; this is because the short-cut method calculates the maximum detention volume required.

Appendix B
Decision Tree for Data Quality Evaluation



Select most reliable data source
Do data meet quality requirements?
Y
N
Use data with full references
Are there other data sources available?
Y
N
Are data crucial?
Y
N
Can data provide relevant, if limited, information?
Do not use
Y
N
Use data but fully describe limitations & document need for better data. If data quality is unknown, a disclaimer will be included (see section 3.3)
Do not use & note need for data collection

Land Use Class (restricted)
Residential
Commercial
Industrial
Highways
Undeveloped/Rural

Point of Analysis	Drainage Area (Acres) by LU Class	Impervious Acres in Drainage Area	Land Use Category	Percent Impervious in Drainage Area	Runoff Coefficient	Pollutant of Interest
C1	0.00	0.00	Commercial	0.0%	0.05	TP
C1	3.71	1.23	Residential	33.1%	0.05	TP
C1	3.54	0.55	Undeveloped/Rural	15.6%	0.05	TP

Pollutant Concentration	Water Quality Volume	Pollutant Load Without Treatment (lbs/year)	BMP Treatment Option	BMP Treatment Volume (ft^3) **(From Additional BMP Sizing Sheet)**
0.2	15	0.0	Bioretention	14
0.3	4,458	0.5	Bioretention	4,447
0.11	2,004	0.2	Bioretention	1,999

Percent of WQV Treated	Percent Pollution Reduction	BMP Pollutant of Interest	BMP Treatment - Percent Reduction	Pollutant Load With Treatment (lbs/year)	Mass Reduction (lbs/yr)	Cost
0.2%	0.1%	TP	30%	0.0	0.0	$165,650
68.7%	20.6%	TP	30%	0.4	0.1	
30.9%	9.3%	TP	30%	0.2	0.0	

Removal Cost (lbs/year)	Low Range Cost Per Treatment Site at -10%	High Range Cost Per Treatment Site at +25%
$927,561	149,085	207,063

Point of Analysis:

BMP Storage Volume 6,461

Linear Bioretention			
Structure Dimensions			
Linear Length (ft):			
Open Storage Depth (ft):			
Width of Bottom Channel (ft):			
Side Slope Ratio (ft):		:	1
Storage Volume (ft^3):	**0**		

Nonlinear Bioretention			
Structure Dimensions			
Base Length (ft):			
Base Width (ft):			
Open Storage Depth (ft):			
Side Slope Ratio (ft):		:	1
Storage Volume (ft^3):	**6461**		

Surface BMP	
Structure Dimensions	
Open Space Area (Acres):	
Percent Open Space Occupied:	
Surface BMP Footprint (Acres):	
BMP Depth (ft)	
Storage Volume (ft^3):	**0**

Subsurface Infiltration	
Structure Dimensions	
Linear Length (ft):	
Storage Depth (ft):	
Bottom Width (ft):	
Storage Bed Material Porocity:	
Storage Volume (ft^3):	**0**

Sand Filter	
Structure Dimensions	
Length (ft):	
Width (ft):	
Filter Bed Depth (ft):	
Storage Volume (ft^3):	**0**

Open Storage

Structure Dimensions	
Length WVTS (ft):	
Width WVTS (ft):	
Depth WVTS (ft):	
Storage Volume (ft^3)	**0**

Point of Analysis	Plat Lot	Drainage Area (Acres)	Impervious Acres in Drainage Area	Percent Impervious in Drainage Area	Water Quality Volume (ft^3)	Pollutant Load Without Treatment (lbs/year)	Pollutant Load WithTreatment (lbs/year)	Mass Reduction (lbs/year)	Cost	Removal Cost (lbs/year)	Percent Reduction
C1	8-29-0	7.25	1.78	24.6%	6,461	0.7	0.6	0.1	$165,650	$927,561	18%

Water Quality BMPs		Median Pollutant Removal Efficiency (%)			
		TSS	**TP**	**TN**	**Bacteria**
WVTS	Shallow WVTS	85%	48%	30%	60%
	Gravel WVTS	86%	53%	55%	85%
Infiltration Practices	Infiltration Basin	90%	65%	65%	95%
	Infiltration Trench	90%	65%	65%	95%
	Subsurface Chambers	90%	55%	40%	90%
	Dry Well	90%	55%	40%	90%
	Permeable Paving	90%	40%	40%	95%
Filters	Sand Filter	86%	59%	32%	70%
	Organic Filter	90%	65%	50%	70%
	Bioretention	90%	30%	55%	70%
	Tree Filter	90%	30%	55%	70%
Green Roofs	Green Roof - Extensive	90%	30%	55%	70%
	Green Roof - Intensive	90%	30%	55%	70%
Open Channels	Dry Swale	90%	30%	55%	70%
	Wet Swale	85%	48%	30%	60%
Storage BMPs (Other)	Wet Extended Detention Basin	80%	52%	31%	70%

Point of Analysis	Plat Lot	Drainage Area (Acres)	Impervious Acres in Drainage Area	Percent Impervious in Drainage Area	Water Quality Volume (ft^3)	Pollutant Load Without Treatment (billion colonies/year)	Pollutant Load WithTreatment (billion colonies/year)	Mass Reduction (billion colonies/year)	Cost	Removal Cost (billion/year)	Percent Reduction
C1	8-29-0	7.25	1.78	24.6%	6,461	13133.6	6956.6	6,177.0	$165,650	$34	47%