Phase 1 and Phase 2: Lincoln Street Subwatershed Nutrient Control Strategies

Incentivizing Resiliency Through Implementation Plans in One of Coastal New Hampshire's Fastest Growing Communities

FINAL REPORT – MARCH 2018

Project:

Water Integration for Squamscott-Exeter (WISE) Integrated Plan

Prepared for:

Town of Exeter, New Hampshire

Prepared by:

Waterstone Engineering and the Rockingham Planning Commission

Funded by:

NOAA Office for Coastal Management
NH Coastal Program

Phase 1 and Phase 2: Lincoln Street Subwatershed Nutrient Control Strategies

Incentivizing Resiliency Through Implementation Plans in One of Coastal New Hampshire's Fastest Growing Communities

FINAL REPORT -- MARCH 31, 2018

Project:

Water Integration for Squamscott-Exeter (WISE) Integrated Plan

Prepared for:

Paul Vlasich, PE, Exeter Public Works
13 Newfields Road, Exeter, NH 03833

Prepared by:

Robert Roseen, PE, PhD,
Jake Sahl, MS
Waterstone Engineering

Julie LaBranche
Rockingham Planning Commission

Phase 1 Funded by:

Sally Soule, Grant Manager
NH Coastal Program, NHDES

Phase 2 Funded by:

Nathalie Morison
Coastal Resilience Specialist
NH Coastal Program, NHDES

Support for this project was provided by the National Oceanic and Atmospheric Administration Office for Coastal Management pursuant to the Coastal Zone Management Act of 1972 in conjunction with the NH Department of Environmental Services Coastal Program, as a FY2016 Project of Special Merit Grant, Award # NA16NOS4190157

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

ACRONYMS

AOC	Administrative Order on Consent
BMP	Best Management Practice
CAP	Climate Adaptation Policy
CSO	Combined Sewer Overflows
CIP	Capital Improvement Plans
CWA	Clean Water Act
EPA	United States Environmental Protection Agency
GBNNPSS	Great Bay Nutrient Nonpoint Source Study
GI	Green Infrastructure
HAZUS	Hazards U.S.
HRU	Hydrologic Response Unit
I/I	Inflow and Infiltration
IP	Integrated Planning
LID	Low Impact Development
MEP	Maximum Extent Practicable
MS4	Municipal Separate Storm Sewer System
NHDES	New Hampshire Department of Environmental Services
NLM	Nitrogen Load Model
NPDES	National Pollution Discharge Elimination System
NPS	Nonpoint source pollution
NRCS	Natural Resources Conservation Service
O&M	Operations and Maintenance
ORIWMP	Oyster River Integrated Watershed Management Plan
PREP	Piscataqua Region Estuaries Partnership
PTAPP	Pollution Tracking and Accounting Pilot Program
ROW	Right-of-way
SSO	Sanitary Sewer Overflow
SWMM	EPA Stormwater Management Model
TMDL	Total Maximum Daily Load
TN	Total Nitrgen
UNH	University of New Hampshire
WISE	Water Integration for the Squamscott-Exeter
WLA	Waste Load Allocation
WQRP	Water Quality Response Plan
WWTF	Wastewater Treatment Facility

ACKNOWLEDGEMENTS

Phase 1

The Phase 1: Lincoln Street Subwatershed Nutrient Control Strategies, Water Integration for Squamscott-Exeter (WISE) was funded, in part, by NOAA's Office for Coastal Management under the Coastal Zone Management Act in Conjunction with the NH Department of Environmental Services Coastal Program. We would also like to acknowledge and express our gratitude to all those who participated in the development of this phase of the report.

Project Team:

Waterstone Engineering
Robert Roseen, Project Director
Jake Sahl, Modeler and Analyst

New Hampshire Coastal Program
Sally Soule, Grant Manager
Steve Couture, Supervisor

Town of Exeter, NH
Paul Vlasich, Town Engineer
Jennifer Mates, Assistant Town Engineer
Jay Perkins, Road Agent
Daniel Lewis, Engineering Technician
Jennifer Perry, Public Works Director

Phase 2

The Phase 2: Incentivizing Resiliency Through Implementation Plans in One of Coastal New Hampshire's Fastest Growing Communities, Water Integration for Squamscott-Exeter (WISE) was funded, in part, by the National Oceanic and Atmospheric Administration as a FY2016 Project of Special Merit Grant, Award # NA16NOS4190157. We would also like to acknowledge and express our gratitude to all those who participated in the development of this phase of the report.

Project Team:

Applicant:
Steve Couture, Coastal Program Manager

Principal Project Manager:
Nathalie Morison, Coastal Resilience Specialist

Rockingham Planning Commission
Julie Labranche, Senior Planner, Project Director

Waterstone Engineering
Robert Roseen, Project Director
Jake Sahl, Modeler and Analyst

Town of Exeter, NH
Paul Vlasich, Town Engineer
Jennifer Mates, Assistant Town Engineer
Jay Perkins, Road Agent
Daniel Lewis, Engineering Technician
Jennifer Perry, Public Works Director
Kristen Murphy, Planner

Project Partners: Great Bay National Estuarine Research Reserve; Steve Miller, Coastal Adaptation Workgroup; and Michael Trainque, Southeast Watershed Alliance

The final report and full appendices can be downloaded at the Rockingham Planning Commission http://www.rpc-nh.org/regional-community-planning/climate-change/exeter-resilience

EXECUTIVE SUMMARY

What is the Lincoln Street Subwatershed Nutrient Control Strategies Report?

This report presents information from two projects, the *Lincoln Street Subwatershed Nutrient Control Strategies (Phase 1)*, and *Incentivizing Resiliency Through Implementation Plans in One of Coastal New Hampshire's Fastest Growing Communities (Phase 2)*, of the *Water Integration for Squamscott-Exeter (WISE) Integrated Plan* (hereafter, 'the Plan'). The projects (conducted from 2016-2018) build upon recommended activities detailed in the Plan which will help satisfy permit requirements for wastewater and stormwater management and increase climate resiliency for municipal drainage infrastructure.

This project provides a plan and design to support the Lincoln Street Capital Improvement Plan for Utilities and Road Reconstruction. The capital project is based on a Complete Streets approach that balances mobility and safety for all users while creating a healthier place – socially, environmentally, and for the local economy. A Complete Streets approach combines the use of green infrastructure with attractive public spaces for the community and local businesses to help reduce nitrogen and flooding from stormwater runoff. This project conducted watershed planning and designs for green infrastructure strategies in the Town's largest subwatershed for use in future CIP, and grant program applications. The project uses recommendations from the 2015 Integrated Plan and involved priority sites with the highest pollutant load that discharge directly to the Squamscott-Exeter River.

Phase 1 of the project has four primary objectives:

1. Increasing municipal capacity to identify and implement feasible and cost effective nutrient control strategies by beginning the implementation of the WISE Integrated Plan through the use of Plan recommendations and best management practice (BMP) sizing tools.
2. Reduce nitrogen load from a series of BMPs throughout the Lincoln Street subwatershed.
3. Increase climate resiliency by reducing flooding through installation of BMPs.
4. Development of construction-ready green infrastructure designs for inclusion in future capital improvement projects in Exeter's largest subwatershed.

Phase 2 of the project has three primary objectives:

1. Achieve municipal capacity building around planning for climate change and flood events.
2. Implement public outreach and communication to build support for and understanding of adaptation planning including economic considerations.
3. Advance green infrastructure, low-impact development, and other effective means of adaptation implementation for flood damage avoidance.

Why Nutrient Control Planning?

New Hampshire coastal communities have experienced rising populations resulting in an increase in development in point source and non-point source nitrogen loads. As communities respond to new federal permit requirements for treating and discharging stormwater and wastewater, meeting regulatory requirements requires innovative ways to find effective and affordable means to meet water quality goals. Integrated Planning allows flexibility in permitting of wastewater and stormwater controls to plan for the most cost-effective measures first while still meeting regulatory standards that protect public health and water quality. It encourages the use of green infrastructure which manages stormwater as a resource, and supports other economic and quality of life benefits. Integrated planning is being shown to have great cost-efficiencies through the comprehensive management of wastewater, stormwater and nonpoint sources.

Why Incentivize Resiliency?

Building community awareness about stormwater flooding, water quality issues, and being adaptable and resilient brings with it the nuances of effective communication methods and strategies. Complex concepts are often challenging for the lay person to comprehend and identify in their own life experience without targeted repetitive exposure and messaging. In the case of the Lincoln Street watershed, several distinct and diverse populations live, work and play in a relatively small geographic area but rarely interact or share common activities or space. Proactive strategies can be identified and implemented that address the impacts of coastal hazards and climate change to create a more sustainable and resilient community. To effect change means to bring about a different state or condition. Incentivizing changes in behavior, attitude or technical capacity around resiliency is a challenging task. Different audiences respond to different messages depending on their age, beliefs, attitudes, education and social position. A person's degree of "social or community capital" can also influence their behavior and choices as being connected to social networks and community often fosters collective actions and collaboration. Local survey results indicate that many communities have adopted proactive actions to address the impacts of climate change and the benefits of resiliency planning, and that informing local land use boards and commissions and decision makers is important and beneficial. An integral component of a community resilience strategy includes the adoption of a guiding policy document. This project developed a draft Climate Adaptation Policy for Exeter which lays out the following vision, purpose, goals and implementation actions to guide the community.

Major Findings

- The total annual nitrogen load from the entire Lincoln Street watershed is 1,265 pounds from 179 acres.
- Installation of BMPs 1, 2, 3, 4, 5, 7, 8 and 9 is expected to reduce this load by 691 pounds annually, a 76% reduction.
- The BMP unit cost performance averaged $1,000 and ranged from $498 - $5,080 per pound of nitrogen, and is estimated to be $1,200 for the new Exeter facility at $3 mg/L.
- Flood reductions are estimated at 60% for the current 10-YR storm and 50% for the future 2040 storm with 9.21 ft of storm surge.
- These activities address requirements of EPA's 2017 NH Small MS4 General Permit for stormwater for nitrogen source identification reporting, and BMP optimization and prioritization.
- A cost impact analysis evaluated the flood damage avoidance potential with green infrastructure.
- The estimated flood loss from a current 10-YR storm is $6.11 million or $3.43 million with green infrastructure, a 51% reduction.
- The total estimated cost to implement green infrastructure at these 14 locations is $689,000 and manages 179 acres.
- The flood reduction benefit is from small sized BMPs with a 0.5" water quality volume.

1. INTRODUCTION

This project summary presents information from the *Water Integration for Squamscott-Exeter (WISE) Integrated Plan Phase 1: Lincoln Street Subwatershed Nutrient Control Strategies* and *Phase 2: Incentivizing Resiliency Through Implementation Plans in One of Coastal New Hampshire's Fastest Growing Communities* by Waterstone Engineering and the Rockingham Planning Commission. The project builds upon recommended activities detailed in the Plan which will satisfy permit requirements for wastewater and stormwater and builds a foundation for adaptation strategies through planning and infrastructure.

a. Phase 1

The study area is Exeter's largest watershed (S10[1]) totaling 179 acres and comprised of 2 subwatersheds, the upper watershed area to the west (S10 West), and the lower area to the east of the railroad tracks (S10 East) which encompasses Lincoln Street. These areas drain underneath Phillips Exeter Academy to a known area of flooding concern along Tan Lane, the location of which makes upsizing sewer infrastructure very difficult. Management of upstream runoff associated with phase 1 will reduce flood vulnerability and provide water quality treatment in a more cost-effective manner than simply upgrading pipe size and capacity. Previous studies[2] used a drainage infrastructure model to identify several areas of concern within the watershed based on the likelihood of flooding. The flood risk at these locations (shown in Figure 3) has been confirmed by town staff. Using geospatial data for stormsewer lines, manholes, catch basins, and topography, drainage infrastructure components were categorized based on their watershed area. This allowed the project team to identify several sites where BMP installations would have large drainage areas and thus a significant potential to reduce flooding and improve water quality within the watershed.

[1] Drainage Area Map Package, Town of Exeter, December 29, 2014
[2] Climate Adaptation for Exeter (CAPE) Project, 2016

Phase 1 of this project identified locations and calculated the potential benefits from BMPs for nutrient management and climate resiliency. Additionally, phase 1 identifies locations of potential BMPs and presents estimates of the nitrogen load and storm volume reduction using BMP performance curves[3]. A suite of 14 priority BMPs were modeled for flood reduction potential and costing and 95% concept designs were completed for each.

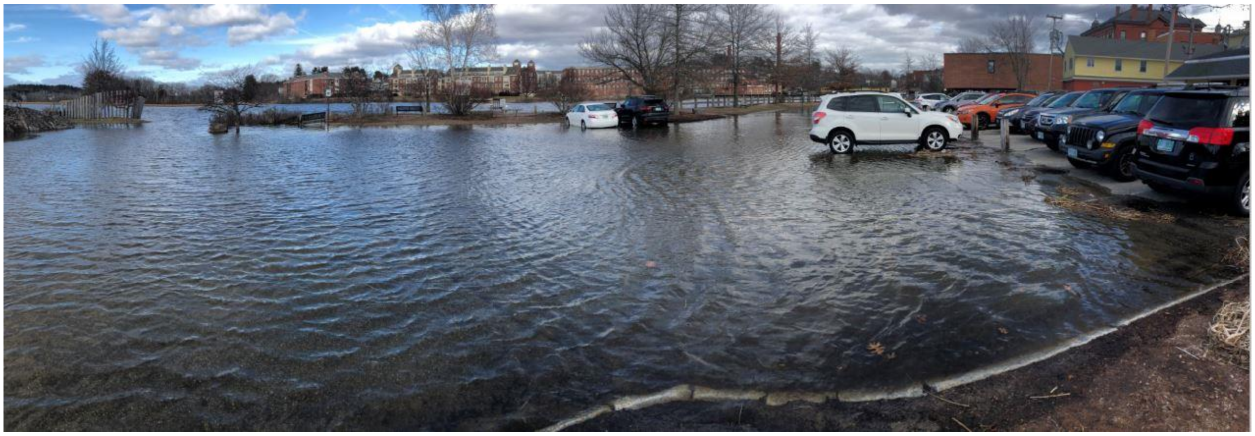


Figure 1: Severe flooding at the town landing March 2018 Noreaster

Figure 2: Flooding along Swasey Parkway from the Squamscott River during the March 2018 Noreaster

b. Phase 2

As populations continue to increase and current land uses undergo development and redevelopment, plans need to be put in place to limit future impacts from projected increases in precipitation and extreme storm events. Exeter's growing population provides both challenges and opportunities for the community to adopt growth management strategies that can increase community resiliency. The Great Bay National Estuarine Research Reserve (GBNERR) and the New Hampshire Coastal Adaptation Workgroup have identified the

[3] Water Integration for Squamscott Exeter (WISE, 2015), Draft Integrated Plan

use of green infrastructure (GI) and low impact development (LID) practices with municipal capacity building as an important climate adaptation measure. The ecosystem service benefits of GI crosscut economic, social, and environmental sectors, and have the potential to minimize today's most pressing environmental problems – flooding from climate change, runoff pollution, and habitat degradation. Combined gray and green infrastructure strategies can be considerably more cost-effective for stormwater management than traditional gray infrastructure approaches and have been demonstrated widely on a large municipal scale across the country.

During phase 2 of this project, the Project Partners worked with community leaders in the Town of Exeter, NH to incentivize resilient development strategies through the development of a subwatershed scale implementation plan and Climate Adaptation Policy (CAP) combined with innovative communications that illustrate the economic benefits of flood adaptation. The Project Team supported the development of *Coastal Resilience Technical Program Assistance* by addressing the identified strategy work plan activity to *improve community education and engage in projects focused on using green stormwater infrastructure as a tool to enhance flood protection and water quality* with the following main project elements:

- The Rockingham Planning Commission (RPC) regional planner worked with the Town of Exeter to develop community-tailored Climate Adaptation Policies. The CAP identifies a framework for integrating resiliency policies into zoning ordinances, regulations, building code, capital improvement plans (CIPs), and design guidelines.
- A vulnerability analysis of municipal drainage infrastructure and shorelands was conducted in combination with an examination of flooding extent and climate adaptation strategies at the subwatershed scale for the purpose of developing site-specific implementation plans and construction ready designs. These implementation plans and adaptation designs can be used as part of future CIPs to assist municipalities with preparing for increases in IC from anticipated growth and impacts from climate change. The CIP will provide specific examples of adaptation strategies including green infrastructure, impervious cover disconnection, expansion and/or protection of buffers, infrastructure upgrades, and shoreland protection and stabilization.
- To more fully explore the benefits of climate adaptation, an economic analysis was conducted to examine the direct fiscal impacts from flooding damage for various planning scenarios. Standard federal practices for damage valuation was used in combination with innovative visualization of flooding impacts.
- Lastly, the Project Partners engaged coastal zone communities with an outreach effort using innovative messaging to communicate the social, economic and environmental impacts from flooding to the public in vulnerable areas. Innovative visualization tools and approaches were installed in key public places to illustrate climate vulnerability in both physical terms that illustrate climate vulnerability in both physical terms, such as flooding and stormwater management, environmental terms such as the impact on water quality, impacts from climate change and sea-level rise, and economic terms such as the risk to the local economy and fiscal impacts.

Incentivizing resiliency through the implementation of climate adaptation strategies and updates to municipal policies in coastal communities can reduce impacts to both the built landscape and natural environment from a changing climate. The 2011 report Climate Change in the Piscataqua/Great Bay Region details extensive current and future climate changes that may impact coastal communities (Wake et al. 2011). Recent analyses examining impacts from climate and land use changes in the Lamprey River watershed indicated a 45% increase in the current 100-year flood flow. However, in urban settings the application of low impact development (LID), while not eliminating flooding, reduced runoff by as much as 46% in locations with high percentages of IC (Wake et al 2013).

2. Background

Like many coastal regions, population growth and development in Exeter has contributed to an increase in impervious cover and has led to increased pollutant loads and stormwater runoff. As more impervious surface is added, flooding risks are elevated, and water quality is impacted. Recent documented changes in climate have resulted in higher-intensity precipitation events, increased rainfall depth, and greater variations in storm duration and frequency which increase these risks and impacts.

In 2009, NHDES concluded that many sub-estuaries in the Great Bay Estuary were impaired by nitrogen, and the Great Bay was placed on the Clean Water Act (CWA) Sec. 303(d) list of impaired and threatened waters (NHDES, 2009). New and revised discharge permits in the watershed are now subject to additional nitrogen requirements including the National Pollutant Discharge Elimination System (NPDES) permits for wastewater treatment facilities, and Municipal Separate Storm Sewer Discharge (MS4) permits for stormwater. In 2012 EPA issued a new NPDES wastewater discharge permit to the Town of Exeter with a total nitrogen (TN) effluent limit of 3 mg/l. The Town subsequently negotiated an Administrative Order of Consent (AOC) with the EPA that allows a staged approach to TN reduction, allowing 5 years to construct a facility to treat nitrogen to meet a limit of 8 mg/l TN, followed by continued upgrades and reductions in TN. The AOC requires a *Total Nitrogen Nonpoint and Point Source Stormwater Control Plan* by September 30, 2018. The plan must include a schedule for implementing specific nitrogen control measures. In addition, the new 2017 NH Small MS4, which becomes effective in 2018, includes significant new elements such as a focus on illicit discharge detection and elimination, and nutrient management through BMP retrofits. The town approved funding for a $49.9 million new wastewater plant in March 2017 through the NH Clean Water State Revolving Loan Fund. Construction began in June 2017 and is expected to be completed in 2018.

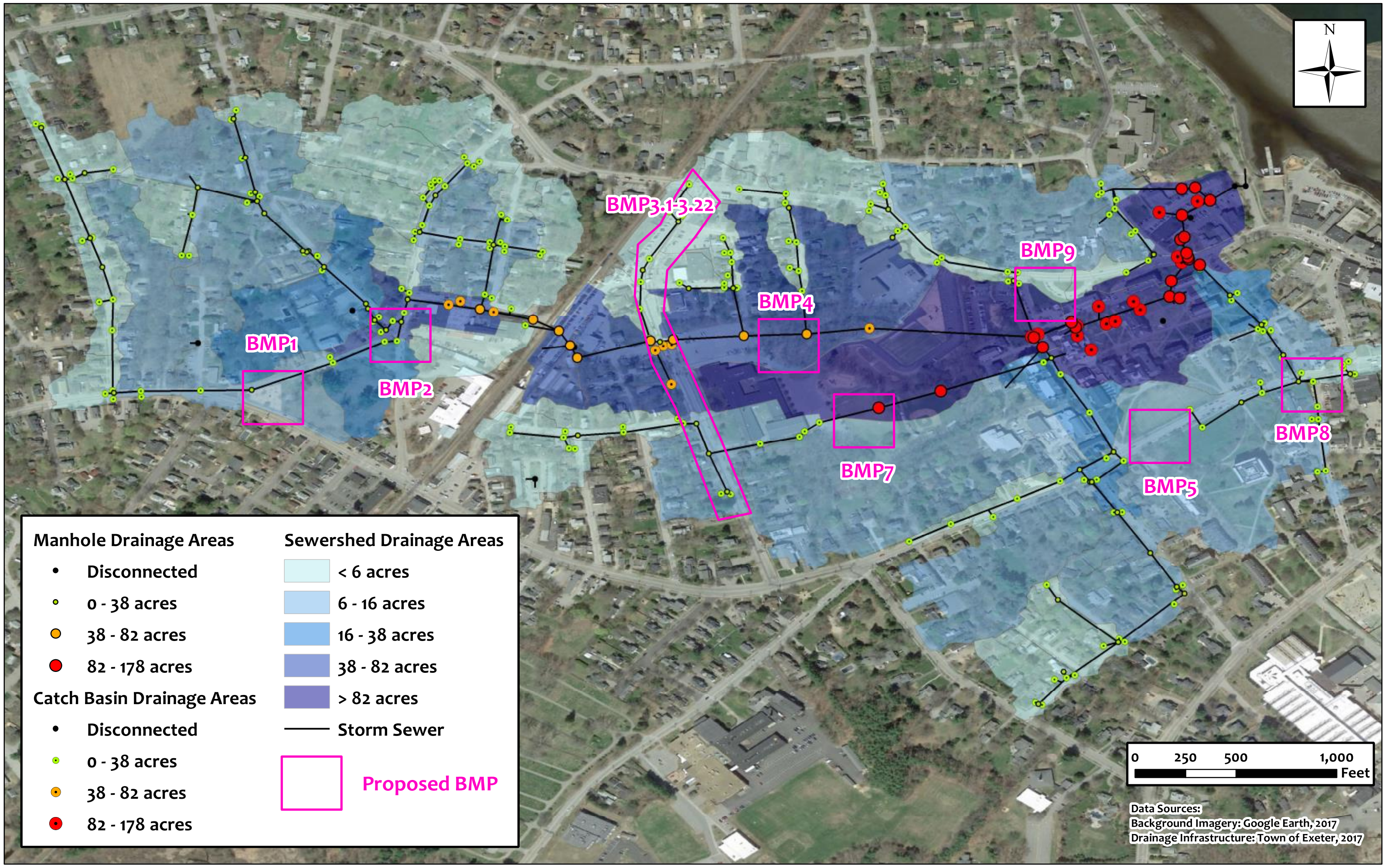


Figure 3: Areas of interest for BMP Retrofit

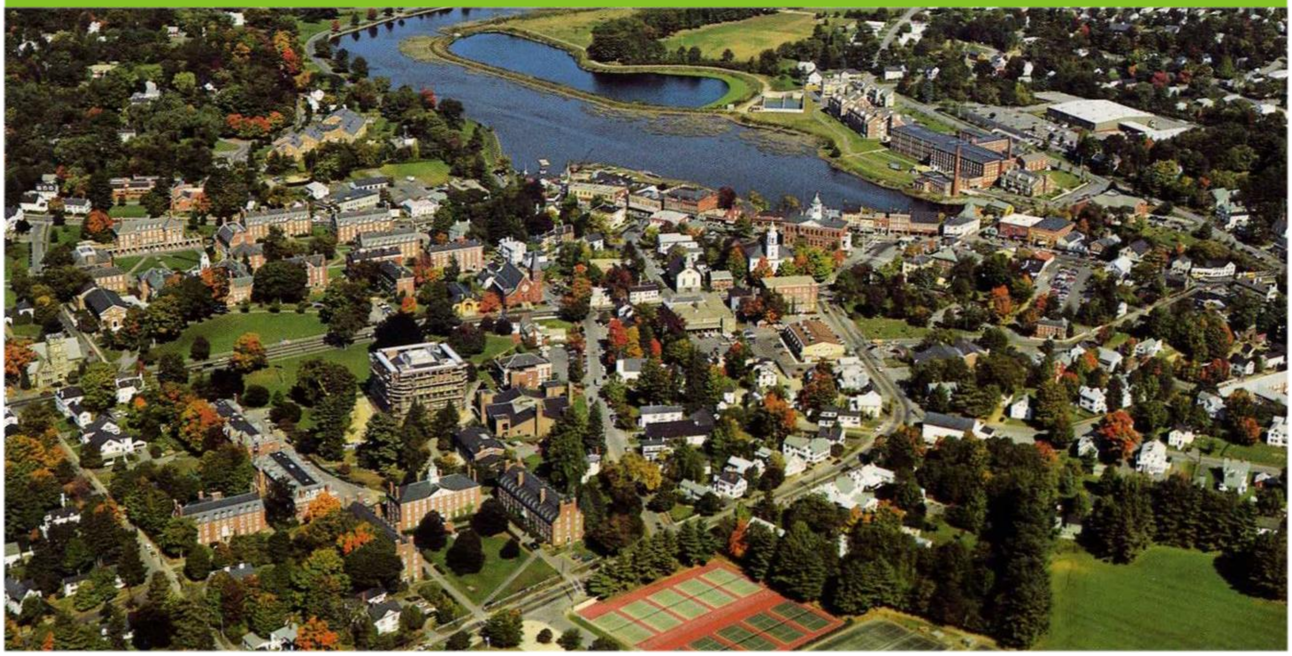
3. STORMWATER MANAGEMENT

In March 2015, the Water Integration for Squamscott-Exeter (WISE) project completed an Integrated Planning framework for three coastal communities including Exeter, Stratham, and Newfields to provide recommendations for affordably managing permits for wastewater and stormwater. A watershed level load model was developed to determine the nitrogen load to the Squamscott-Exeter estuary. The results represent a baseline assessment to quantify the economic and performance advantages of integration of water resource planning both at the municipal and inter-municipal level. This project seeks to build upon the WISE analysis to identify specific green infrastructure (GI) and low impact development (LID) practices that can be installed in Exeter to manage stormwater, reduce nutrient loads, and increase resiliency.

The new 2017 MS4 permit requires management of existing stormwater runoff in impaired watersheds. While new development is required to manage stormwater on-site, existing developments were constructed before stormwater management was required and modern criteria established. Retrofits include new installations or upgrades to existing best management practices (BMPs) in developed areas draining to impaired waters and their tributaries.

BMPs for stormwater management and nitrogen controls include both structural and non-structural practices to reduce runoff volume from stormwater sources such as impervious surfaces (rooftops and parking lots), residential areas, commercial/industrial/institutional properties, roads, outdoor recreational spaces (i.e., parks), agricultural areas, and managed turf (i.e., golf courses, lawn). Common BMPs for nutrient controls include biofiltration (bioretention, raingardens, tree planters), gravel wetlands, infiltration practices (dry wells, and subsurface infiltration), and porous pavements. The Plan lists a range of BMPs that were reviewed and vetted by the towns with respect to land use and practicality. A wealth of BMP sources exists in the literature and locally at the UNH Stormwater Center. A list of practices can be found in the New Hampshire Stormwater Manual on the NHDES website.

4. WATERSHED OVERVIEW



a. Watershed Status and Regulatory Framework

The 2018 State of Our Estuaries report by the Piscataqua Region Estuaries Partnership (PREP) presented a synthesis of 23 indicators of estuarine health illustrating the estuary continues to decline and is under stress. Of the 16 environmental indicators, 12 are characterized as having cautionary or negative trends. Increases in nitrogen loading continue and before recent reductions from municipal wastewater treatment facilities (WWTF), point source nitrogen loading levels had increased steadily between 1988 and 2012 with non-point source (NPS) nitrogen loading peaking between 2006 and 2008 due to the extreme precipitation. At 43.6 tons per square mile (of tidal estuary surface area), nitrogen levels between 2012 and 2016 were much higher than the 14 tons per square mile threshold for eelgrass health indicated in a 2010 study of 62 New England estuaries. Municipalities have made recent, substantial improvements to their WWTFs to reduce the amount of total nitrogen they discharge with Rochester, Dover, and Newmarket having recently completed major upgrades; Durham has reconfigured its facility; and Portsmouth, Newington, and Exeter are in the process of upgrading their treatment plants. Each of these upgrades should result in important nutrient reductions in the form of wastewater effluent.

EPA is required to develop criteria (numeric or narrative) based on a determination that there exists a reasonable potential to cause or contribute to an impairment[4]. This determination is based on 'the best available science' at the time, which acknowledges that although our understanding of an ecosystem is necessarily incomplete, further delay in corrective measures will clearly contribute to increasing degradation. Permits may be issued to comply with numeric or narrative criteria. In 2009 NHDES

[4] Pg. 143, Section 5. Reasonable Potential Analysis and Effluent Limit Derivation, EPA. (2012). "Authorization to Discharge Under the National Pollutant Discharge Elimination System, The Town of Exeter, New Hampshire, Squamscott River." NPDES Permit No. NH0100871, Office of Ecosystem Protection, U.S. Environmental Protection Agency, Region I, Boston, Massachusetts.

developed draft numeric nutrient criteria for the protection of eelgrass and low dissolved oxygen conditions. In the absence of final numeric criteria EPA asserts the obligation and authority to issue effluent limitations based on narrative criteria and in 2012 EPA issued final WWTF discharge permits in Newmarket and Exeter based on a narrative TN nutrient criteria and a reasonable potential analysis. A 2014 Peer Review was critical of the draft numeric criteria after which the criteria were dropped as part of a 2014 settlement agreement between NHDES and the Municipal Coalition[5]. The standard upon which the Peer Review was tasked to review the draft numeric criteria was in part…" whether the available data support the conclusion that excess nitrogen was the primary factor that caused (1) the decline of eelgrass populations…"[6] This determination as the "primary factor that caused" is a higher standard than a "reasonable potential to cause or contribute". In 2012 the Environmental Appeals Board and, in 2013 the Supreme Court, upheld the basis for this finding by EPA in determining effluent limitations[7]. In 2016, the Piscataqua Region Estuaries Partnership reconvened the technical advisory committee to review indicator trends and status. In so doing they convened a panel of experts including Jud Kenworthy, the eelgrass expert from the Peer Review, to review eelgrass stressors. They affirmed the position that nitrogen was indeed a major factor and has a reasonable potential to cause or contribute to the environmental problem.

b. Watershed Land Use and Growth Trends

Exeter has experienced substantial growth during the past 50 years. Understanding and mitigating impacts due to population increase, changes in land use and cover, and imperviousness are an essential element of effective management strategies. Since 1960 Exeter has experienced 98% population growth and a 20-year increase in impervious cover of 108% (Figure 2).

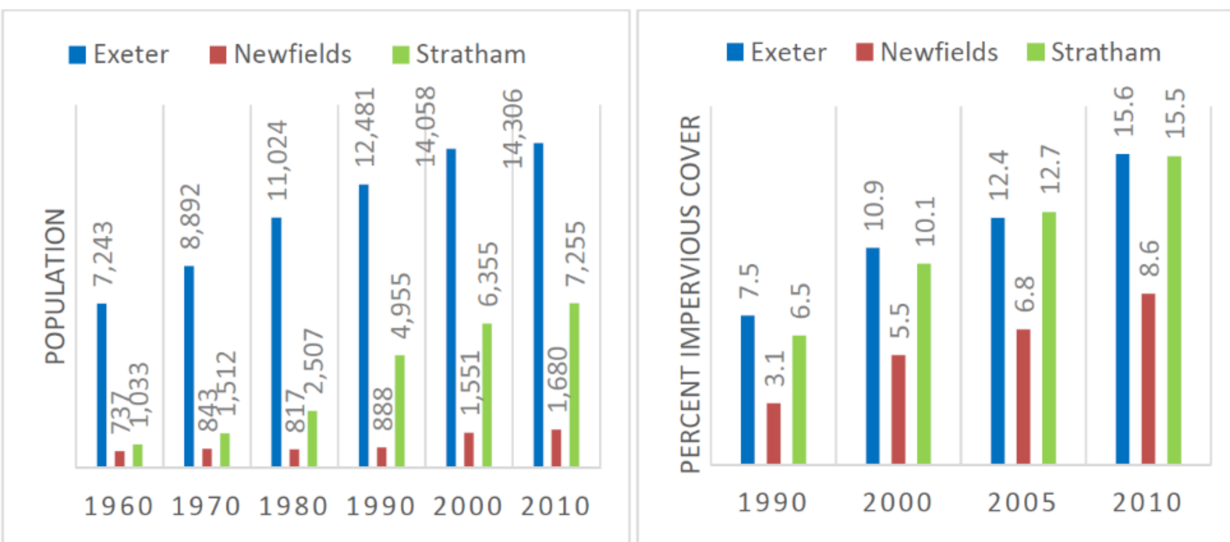


Figure 4 - Population and Impervious Cover changes in the Towns of Exeter, Newfields and Stratham

The study area is comprised of 2 distinct watersheds in terms of drainage infrastructure, the upper watershed area to the west (S10 West), and the lower area to the east of the railroad tracks (S10 East) as displayed in Figure 4. The total watershed is 41% impervious cover, 179 acres, and contributes an estimated 1,265 lbs of nitrogen annually, as shown in Table 1. The watershed land use is predominantly commercial, residential,

[5] April 2014, Settlement Agreement between the Great Bay Municipal Coalition (Portsmouth, Dover, Rochester, NH) and the State of New Hampshire.

[6] Pg 46, section b) from the "Joint Report of Peer Review Panel-Great Bay Estuary", February 13, 2014 Victor J. Bierman, Robert J. Diaz, W. Judson Kenworthy, Kenneth H. Reckhow.

[7] (2012). "Upper Blackstone Water Pollution Dist. v. EPA." F. 3d, Court of Appeals, 1st Circuit, 9.

and roadways. The upper watershed is 57 acres and contributes an estimated 390 lbs of nitrogen annually (Appendix F: Watershed Modeling). The lower watershed, including Lincoln Street, is the larger of the two at 122 acres and contributes an estimated 876 lbs of nitrogen annually. These areas all drain into a 27" storm drain underneath Phillips Exeter Academy to a known area of flooding concern along Tan Lane, the location of which makes upsizing very difficult. Management of upstream runoff will reduce flood vulnerability and provide water quality treatment in a more cost-effective manner than simply upgrading pipe size and capacity. The growth trends in the area will require planning efforts and administrative tools to protect water quality. Communities are all in need of cost-effective strategies from meeting permit requirements to assist in balancing the range of competing municipal demands.

Table 1: Lincoln Street Total Watershed Characteristics

Land Use Type	Hydrologic Soil Group*	Area (acres)	Annual Nitrogen Export (lbs)**
Agriculture	A	0.04	0.02
	C/D	0.47	1.51
Commercial, Services, and Institutional	A	6.44	3.42
	C/D	15.48	41.48
	IMP	30.72	424.48
Forest	A	3.62	1.01
	C/D	2.69	3.88
	IMP	0.02	0.27
Industrial and Commercial Complexes	C/D	0.00	0.01
	IMP	0.77	10.64
Outdoor and Other Urban and Built-up Land	A	1.83	2.00
	C/D	6.15	34.07
	IMP	0.48	6.62
Residential	A	20.41	10.82
	C/D	47.59	127.53
	IMP	26.26	413.04
Transitional	A	0.09	0.02
	C/D	0.23	0.31
	IMP	0.19	2.68
Transportation, Communications, and Utilities	A	0.16	0.04
	C/D	0.14	0.17
	IMP	16.17	182.87
Totals		**179**	**1,265**

* Hydrologic soil group derived from landform. Watershed area was divided into 3 slope classes, 0-3%, 3-8%, and 8-15%. Dominant soil type for each slope class was assumed for entire slope class. Scitico silt loam for 0-3% slopes, Charlton fine sandy loam for others. **Based on WISE, 2015 PLERs

c. Environmental Impacts from Growth

Monitoring and research conducted by various university, local, state and federal programs and projects have documented stresses in the Great Bay system. Prominent drivers of change include watershed modification and development resulting in increased impervious cover; increased nutrient and pollutant loading from a rapidly growing coastal population; and ecosystem instability and loss of diversity caused by invasive species, habitat destruction, disease, and others. Each stress drives additional physical, chemical, and biological pressures on the Great Bay system that effect the environmental, lifestyle, and economic benefits valued by local communities. Environmental indicators used by the National Estuaries Program to identify and track ecosystem health clearly illustrate an ecosystem in trouble. In the most recent State of Our Estuaries 2018 report (PREP, 2018), of the 16 environmental indicators, 12 are characterized as having cautionary or negative trends. Increases in nitrogen loading continue and before recent reductions from municipal wastewater treatment facilities (WWTF), point source nitrogen loading levels had increased steadily between 1988 and 2012 with non-point source (NPS) nitrogen loading peaking between 2006 and 2008 due to the extreme precipitation. At 43.6 tons per square mile (of tidal estuary surface area), nitrogen levels between 2012 and 2016 were much higher than the 14 tons per square mile threshold for eelgrass health indicated in a 2010 study of 62 New England estuaries. While the Great Bay Estuary may have traits that make it more tolerant of high nutrient levels (such as high flushing rates), the system has three times the threshold level from that study, which is a concern. Nutrients fuel the growth of phytoplankton and seaweed and make it more difficult for light to reach eelgrass beds. Seaweed percent cover at intertidal monitoring sites increased from 8% in 1980 to 19% in 2016. Excessive seaweed and phytoplankton growth also can lead to low dissolved oxygen levels.

d. NPDES Wastewater Permit and Administrative Order of Consent

A $49.9 million wastewater treatment plant was approved by voters at the 2016 Town Meeting. The project is financed through a NHDES Clean Water State Revolving Fund totaling $53,580,000 with $5 million of principal forgiveness. The wastewater treatment plant is expected to be finished in June 2019.

EPA Region 1 issues individual facility-specific permits for the discharge of treated domestic and industrial wastewater in the State of New Hampshire. Under these individual permits, the discharges will be limited and monitored by the permittee. Of the three WISE watershed communities, the Towns of Exeter and Newfields operate and discharge treated domestic wastewater.

In 2012 after several years of study and negotiations, EPA issued a new NPDES discharge permit to the Town of Exeter with a total nitrogen (TN) effluent limit of 3 mg/l. The Town subsequently negotiated an Administrative Order on Consent (AOC) with the EPA that allows a staged approach to TN reduction which allows 5 years to construct a facility which will treat nitrogen to meet a limit of 8 mg/l TN, followed by continued upgrades and reductions in TN. The AOC requires tracking and monitoring to ensure that load reductions goals and ecosystem response are on target.

e. Municipal Separate Storm Sewer System (MS4)

Under the MS4 program, towns with urbanized areas as defined by the US Census are required to obtain permit coverage for their stormwater discharges. Exeter is subject to the requirements of EPA’s 2017 NH Small MS4 General Permit for stormwater discharges. EPA released a final permit in 2017 which will begin in June of 2018 and contains new provisions for the 6 Minimum Measures (MM):

1) Public Education and Outreach
2) Public Participation/Involvement
3) Illicit Discharge Detection and Elimination
4) Construction Site Runoff Control
5) Post-Construction Runoff Control

6) Pollution Prevention/Good Housekeeping

The permit also includes new requirements to develop Nitrogen Source Identification Report; and new development and redevelopment stormwater management BMPs be optimized for nitrogen removal; retrofit inventory and priority ranking to reduce nitrogen discharges.[8]

f. EPA Integrated Planning Framework and Watershed Based Planning

The June 2012 EPA memorandum, "Integrated Municipal Stormwater and Wastewater Planning Approach Framework" provides guidance for EPA, States and local governments to develop and implement effective integrated plans that satisfy the CWA. The framework outlines the overarching principles and essential elements of a successful integrated plan which includes:

- Maintaining existing regulatory standards that protect public health and water quality.
- Allowing a municipality to balance CWA requirements in a manner that addresses the most pressing public health and environmental protection issues first.
- The responsibility to develop an integrated plan rests on the municipality that chooses to pursue the approach. EPA and/or the State will determine appropriate actions, which may include developing requirements and schedules in enforceable documents.
- Innovative technologies, including green infrastructure, are important tools that can generate many benefits, and may be fundamental aspects of municipalities' plans for integrated solutions.

The elements in the WISE plan are consistent with guidance issued by EPA to support integrated permit planning, as well as the Agency's nine-element watershed plans.

g. Municipal Regulations

For the Integrated Plan to be effective, future regulations will need to be adopted by Exeter that include: 1) provisions for new and redevelopment projects to require nitrogen controls, and 2) a means for tracking changes in significant land use activities that will impact the nitrogen load to surface waters. Exeter is participating in PTAPP (the Pollution Tracking and Accounting Pilot Program) which in June 2017 developed a draft uniform approach using a web based application that can be used by communities for MS4 and AOC tracking and accounting.

The March 2015 Piscataqua Region Environmental Planning Assessment report (PREPA) recommends Exeter adopt fertilizer application buffers for all surface waters, increase the no vegetation disturbance to 100' on tidal wetlands, and adopt the Southeast Watershed Alliance Model Stormwater Management Regulations.

h. Southeast Watershed Alliance Model Stormwater Management Regulations

The Southeast Watershed Alliance developed model stormwater standards in 2012, and revised in 2017, to provide minimum, consistent, and effective model stormwater management standards for communities in the Great Bay. These standards are intended to address some of the requirements for communities subject to the MS4 permit. The model standards include 7 critical core elements: Applicability Standards, Minimum

[8] Appendix H: Requirements Related to Discharges to Certain Water Quality Limited Waterbodies, Part I, 1.a.i.2 and Part I, 1.b.

Thresholds for Applicability, Best Management Practices, Applicability for Redevelopment, Stormwater Management Plan Approval and Recordation, Maintenance Criteria, Inspection of Infrastructure.

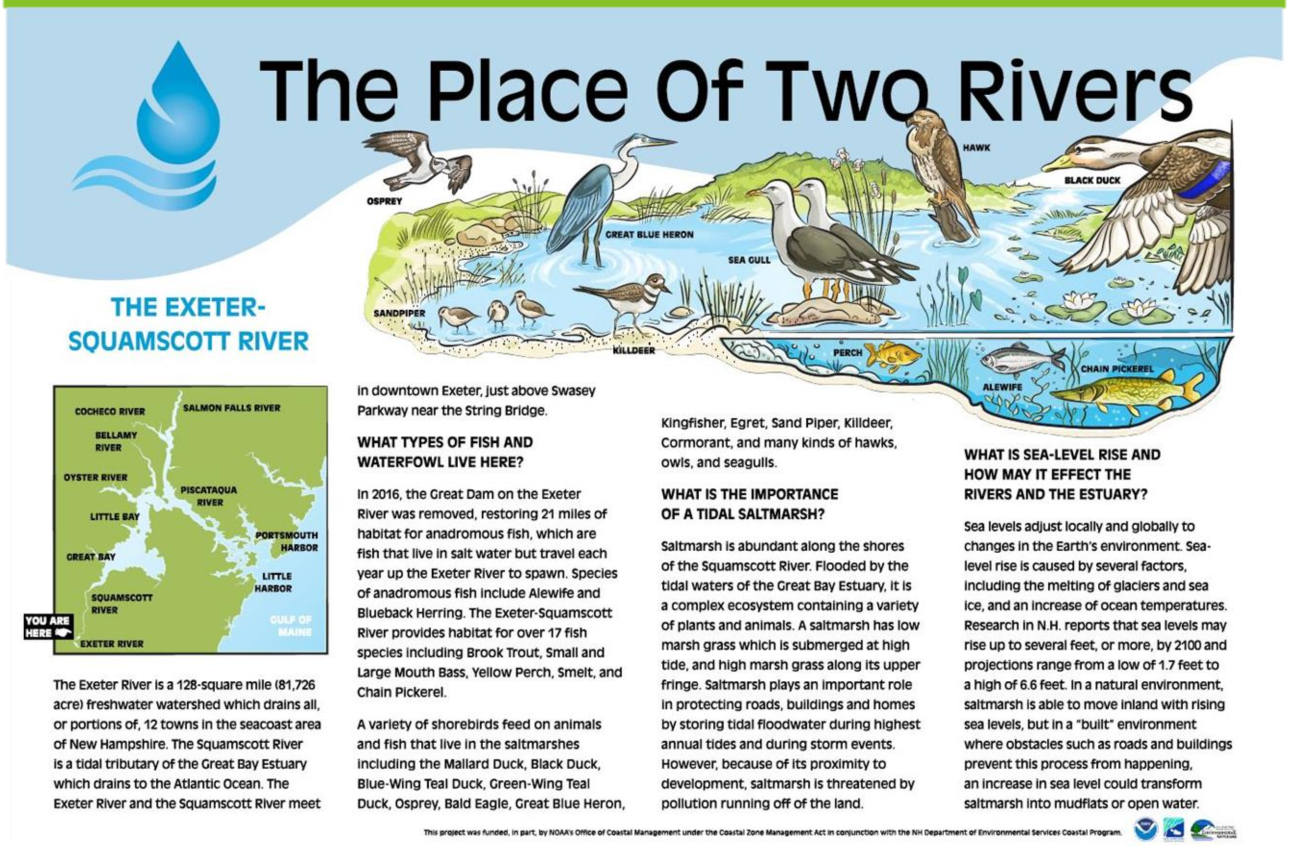
i. Impaired Waters

The Clean Water Act requires each state to submit a list of impaired waters to the U.S. Environmental Protection Agency every two years. Listing of impaired waters (303d list) includes surface waters that:

- Are impaired or threatened by a pollutant or pollutant(s),
- Are not expected to meet water quality standards within a reasonable time even after application of best available technology standards for point sources or best management practices for nonpoint sources and,
- Require development and implementation of a comprehensive water quality study (i.e., called a Total Maximum Daily Load or TMDL study) that is designed to meet water quality standards.

As of the final 2008 listing, the impaired waters within the Town of Exeter include: Dudley Brook; Norris Brook; Little River; Squamscott River; Wheelwright Creek- Parkman Brook; Exeter River; Colcord Pond; and Little River – Scamen Brook. Under the MS4, Exeter is required to manage the drainage area and infrastructure to receiving waters and implement controls to reduce sources of impairments.

5. Innovative Messaging and Outreach



Phase II of the project worked with a communications specialist to develop innovative messaging using multi-media tools, gain feedback from municipal representatives, and test the innovative messaging with stakeholder groups. Following is a description of the project team's modified approach to selecting an innovative messaging strategy.

Approach

The 179-acre Lincoln Street Watershed has a diverse development pattern consisting of semi-rural residential development the uppermost portion and urban development in the lower portion. The urbanized area has commercial, retail, mixed uses, residential neighborhoods, three academic institutions, and a combined commuter rail (The Downeaster) and freight rail line. With these characteristics in mind, the project team evaluated options for an innovative communications strategy based on the following questions.

Basis for Innovative Communications

<u>What is unique about the watershed or area of interest?</u>

Its diverse land uses, academic institutions, and urban and semi-rural landscapes.

<u>What resources are important, prominent, and tell the stormwater story?</u>

The well-developed urbanized stormwater conveyance systems, mostly subsurface, throughout the watershed.

<u>What is the placed-based connection?</u>

Two elementary schools are located in the lower watershed, immediately adjacent to one another.

Who are the key stakeholders to engage?

A discrete, established population that is accessible and open to engagement activities.

What is the community benefit?

Sustained, customized messaging that educates the discrete population about stormwater and resilience concepts.

Goals for Innovative Communication Strategy

Identify the Audience: Main Street Elementary School and Lincoln Street Elementary School

Maximize Exposure: Total student population of 985 children preschool to grade 5

Develop Impactful Message(s): Natural and man-made features on both campuses that illustrate water flow, stormwater, flooding, pollution, and natural water resources

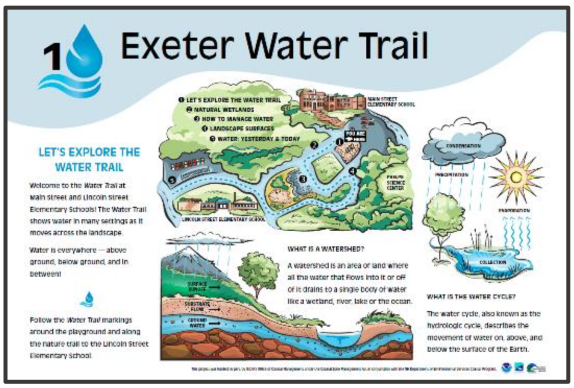
Repeatable Messages(s): Message(s) reach children for possibly 7 consecutive years from preschool to grade 5

Permanent Installation: Educational signage installation utilizing both campuses

Our evaluation of innovative communications options resulted in selection of a permanent installation - The Exeter Water Trail - at the Main Street Elementary School and Lincoln Street Elementary School campuses and Swasey Parkway (a local riverfront public park). The six Exeter Water Trail signs (and installation posts/hardware) have been produced and purchased, and will be installed in May/June 2018.

a. Innovative Messaging - Exeter Water Trail

The Exeter Water Trail is an educational installation on the adjoining campuses of the Main Street and Lincoln Street Elementary Schools. The Trail consists of 5 signs located at various landscape features that illustrate concepts relating to water. Topics such as stormwater runoff, water quality, flooding, watersheds and the water cycle are displayed in brightly colored graphic images and narrative explanations. Companion Water Trail Activity Sheets are provided for Pre-school-grade 3 and grades 4-5 which contain customized content and activities appropriate for the target age group and reading level.

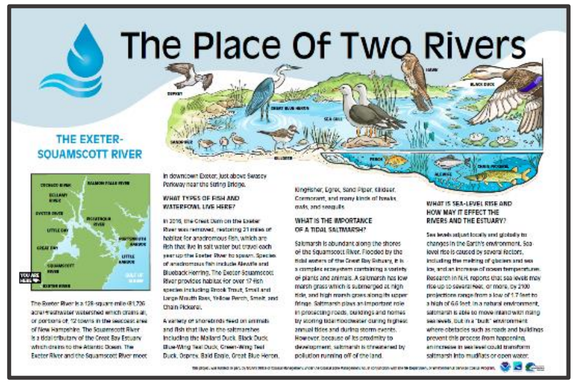


Measures of Messaging Success

As of March 2018, the Main Street Elementary School and Lincoln Street Elementary School have a combined student population of 985 Pre-School-Kindergarten through grade 5 population. As the students' progress from grade to grade, their learning and reading skills will develop which will enhance their understanding of the concepts presented in the Water Trail signage. By the time a student reaches grade 5 it is anticipated that they will have mature comprehension and working knowledge of these concepts. In addition, the outdoor facilities at the Main Street Elementary School and Lincoln Street Elementary School are open to the public during non-school hours including weekends. The campuses include a playground and ballfields which draw many visitors to the site. Addition of the Water Trail will be a substantial resource for visitors. The Water Trail signs are attached in Appendix B: Outreach Efforts.

Swasey Parkway Installation

A sixth Water Trail sign will be installed at Swasey Parkyway, a public park bordering the Exeter-Squamscott River in the heart of historic downtown Exeter. The sign content includes information about the Exeter-Squamscott Rivers watershed, the importance of saltmarsh ecosystems and flood storage functions, the importance of freshwater and tidal riverine ecosystems, and potential future impacts of sea-level rise on these aquatic and terrestrial ecosystems. Swasey Parkway is a highly visited destination by both local residents and visitors, and hosts the spring-fall farmers market every Thursday afternoon. The sign will provide permanent messaging about important resiliency concepts. The Parkway Trustees are delighted with the sign and hope to expand this part of the Exeter Water Trail with future installations.



Exeter Climate Change Open House

On February 6, 2018, the Town of Exeter hosted a Climate Change Open House as part of the Setting SAIL project (funded by a Project of Special Merit grant from NOAA and the NH Department of Environmental Services Coastal Program). The Exeter Water Trail was a featured display at this event which more than 60 people attended. Fourteen attendees responded to a survey for the Water Trail Display. Feedback was unanimously positive particularly about the use of art to communicate complex water related concepts and targeting elementary school students with this type of innovative messaging about the environment.

b. SOUTHEAST WATERSHED ALLIANCE: STAKEHOLDER TRANSFER WORKSHOP

The project deliverable was to design and implement a workshop with the Southeast Watershed Alliance (SWA) with input from the Coastal Adaptation Workgroup to inform their membership about project findings, transferable methods and policies and messaging materials, including a needs assessment of the target workshop participants.

Stakeholder Needs Assessment/Survey

The Stakeholder Need Assessment was executed as an online survey distributed to the SWA member communities. The survey received 27 responses. Following is a summary of the survey results. The full survey results are provided in Appendix B: Outreach Efforts.

- Yes 81% Q1: Does your municipality consider severe weather events and changing environmental conditions a priority issue?
- Yes 67% Q2: Has your municipality conducted a vulnerability assessment either for sea-level rise or freshwater flooding?
- Yes 70% Q3: Do municipal planning staff and engineering/infrastructure management staff understand and/or apply the positive co-benefits that resiliency planning can have on stormwater management, flooding, and water quality?
- Q9: Has your municipality adopted any specific policies or plans that address:
  25% Impacts of climate change (sea-level rise, precipitation, increased storm intensity)
  25% Climate change adaptation actions that limit vulnerability to impacts (for example, accommodating change such as increased precipitation)

50% Resiliency strategies (for example, actions that reduce or minimize harmful impacts)

- Q11: What groups or audiences in your community would most benefit from receiving information about local flooding and climate change impacts?

  28% Civic Groups
  52% Local Decision Makers
  60% Land Use Boards/Commissions
  20% Other Groups (12-property owners/beach residents, 2-developers/engineers, 1-neighborhood/community/chamber of commerce)

The survey results indicate that most communities have adopted proactive actions to address the impacts of climate change and the benefits of resiliency planning, and that informing local land use boards and commissions and decision makers is important and beneficial.

Southeast Watershed Alliance Workshop Summary

On March 28, 2018, the Exeter Stormwater Resilience Project team present a workshop to the Southeast Watershed Alliance (SWA) membership. The workshop featured details of project outcomes and the project framework was described in terms of transferable methods and processes that other municipalities could utilize in their own planning and resilience initiatives.

- Innovative Messaging and Communications
- Climate Adaptation Policy – Planning, Design, Implementation
- Stormwater Flooding in an Urbanized Watershed
- Stormwater Best Management Practices and Green Infrastructure
- Climate resiliency and co-benefits (water quality, flood volume reduction/control, resilience)

Workshop attendees expressed interest in duplicating the Water Trail concept in their communities, and were interactive during the technical presentation about nutrient reduction and flood damage model results. Attendees agreed this type of data would be informative for use in local planning and decision making, and adoption of appropriate climate adaptation and resiliency actions to address current and future flood impacts. The SWA workshop Powerpoint presentation is provided in Appendix B: Outreach Efforts.

Exeter Water Trail

The Exeter Water Trail signage was displayed at the SWA workshop. Attendees completed a brief survey. Survey results and presentation discussion reported that attendees overwhelmingly supported the Water Trail concept and installation, particularly the focus on elementary school students as the primary audience. Several SWA members voiced interest in replicating the Water Trail in their communities.

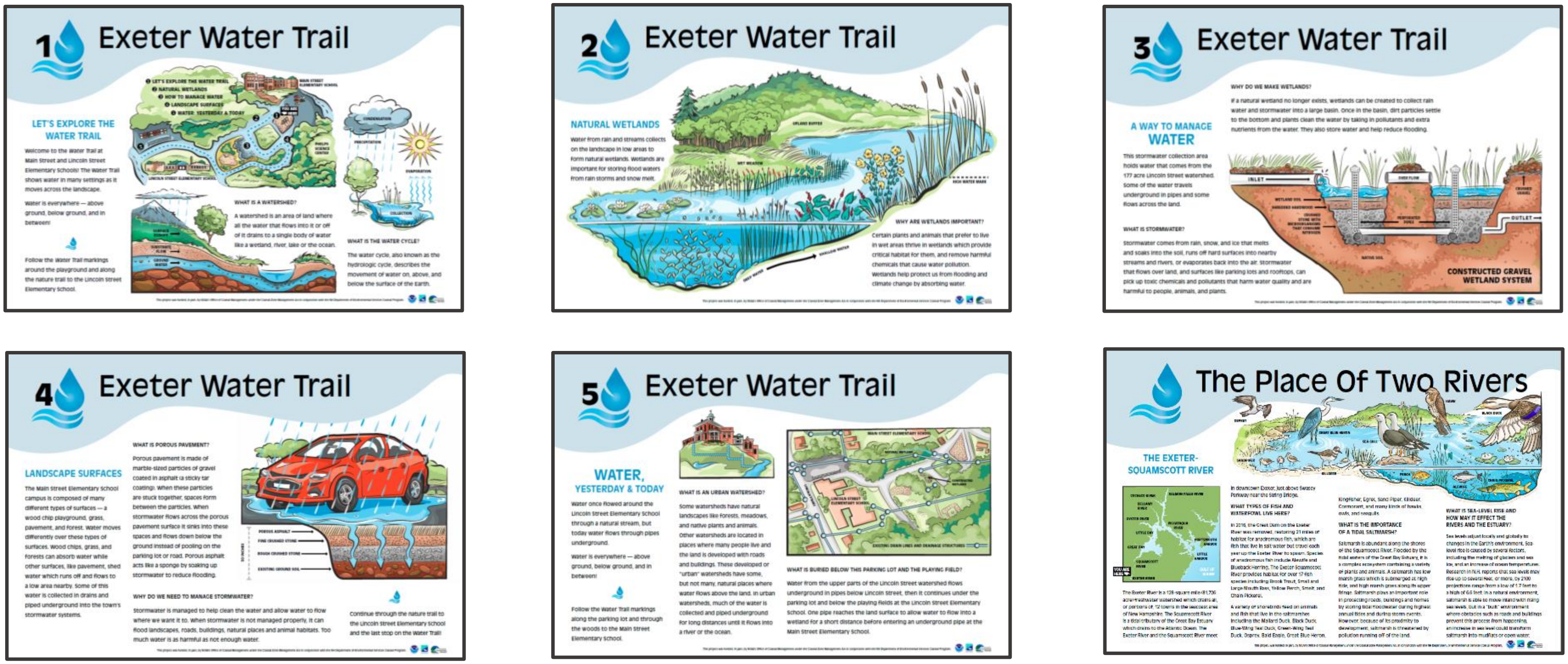
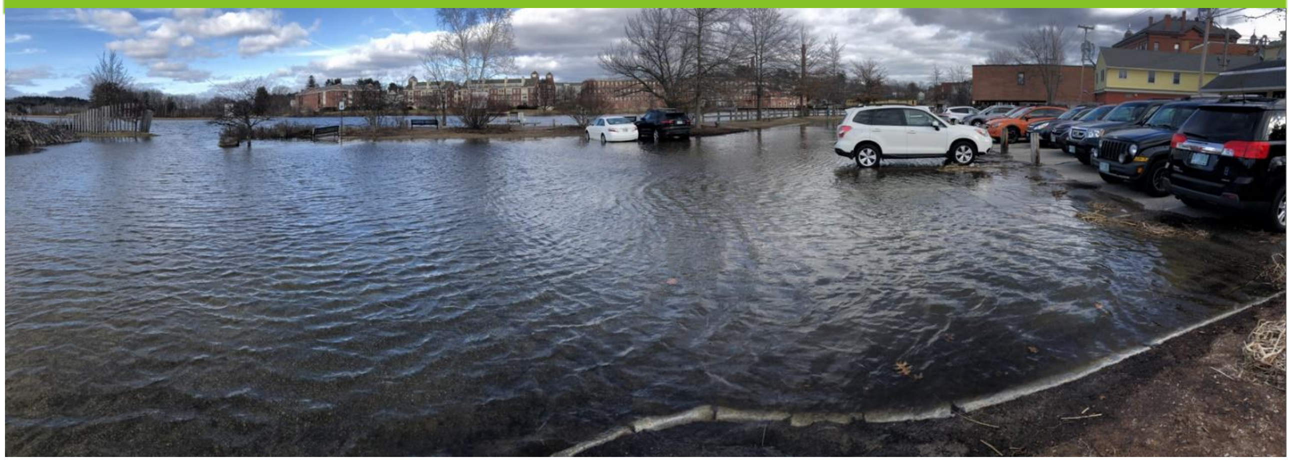


Figure 5: Exeter Water Trail Signage - Innovative Communications by Educational installation at Main Street and Lincoln Street Elementary Schools

6. Climate Adaptation Policy



The project deliverable was to prepare a model/draft Climate Adaptation Policy (CAP) for Exeter with input and review from the project team and municipal decision makers, staff and community stakeholders to identify principles on which to base the CAP and specific needs and opportunities in the community. The draft Climate Adaptation Policy for Exeter was submitted in March 2018 to town staff, officials and land use boards and commissions for review and comment, and for consideration to adopt as an official policy for the town. The Climate Adaptation Policy document is provided in Appendix C: Climate Adaptation Plan.

a. Overview of Climate Adaptation Policy for Exeter

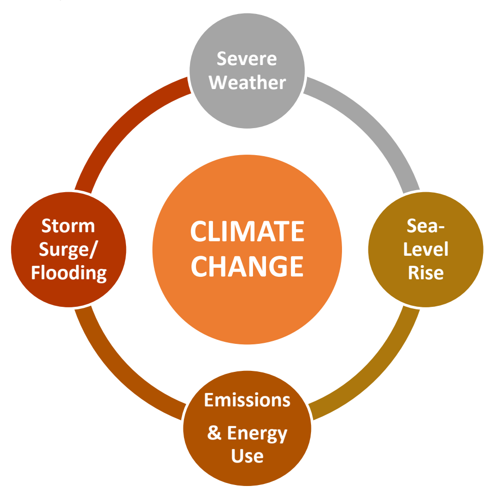
Vision Statement

"Proactive strategies are identified and implemented that address the impacts of coastal hazards and climate change to create a more sustainable and resilient community."

Purpose

The purpose of Exeter's Climate Adaptation Policy is to:

- Establish unified vision, goals, and implementation actions
- Guide planning, investment, infrastructure management, regulations
- Support future grant proposals and other funding sources
- Create a living document, informed by best available science and information



b. Goals and Implementation Actions

The goals of Exeter's Climate Adaptation Policy are to:

- Ensure the community is better prepared to protect the security, health and safety of its citizens.
- Protect natural resources from the impacts of flooding from sea-level rise and storm events.

- Provide for a stable and viable economic future.
- Minimize the future costs of infrastructure replacement and maintenance.
- Support installations of renewable energy systems and electric vehicle charging stations.

Implementation actions are organized around five themes including 31 specific actions: *Municipal Policy and Actions, Management and Investment, Environment-Natural Resources, Regulatory and Land Use Planning, and Community-Based.*

c. Framework for Integrating Resiliency Policies at the Municipal Level

Integrating resiliency policies and developing a Climate Adaptation Policy at the municipal level requires that certain elements are in place. A Climate Adaptation Policy must be ***tailored to the degree and extent of risk and exposure to climate change related impacts***.

Preparation of the (draft) Exeter Climate Adaptation Policy included ***review of critical plans, regulations, and guidance documents***.

- ✓ Audit of Zoning and Land Development Regulations
- ✓ Audit of Master Plan (2017 draft update pending Planning Board adoption)
- ✓ Review of Capital Improvement Plan and Infrastructure/Facilities Management Plans
- ✓ Evaluation of degree and type of exposure, risk and impacts from climate change (e.g. Coastal Risk in the Seacoast (C-RiSe) vulnerability assessment)

Preparation of the (draft) Exeter Climate Adaptation Policy included ***evaluation of community readiness*** to act on climate adaptation and resiliency.

- ✓ Supported by Master Plan
- ✓ Successful, Sustained Community Initiatives and Activities
- ✓ Community Support for Ballot Initiatives and Actions (e.g. 2016 Selectmen Proclamation to uphold the principles of the Paris Climate Accord)
- ✓ Coordination Between Elected Officials, Staff, Boards, Commissions
- ✓ Participation in Regional Assessments and Grant Funded Projects (e.g. Coastal Risk in the Seacoast (C-RiSe) vulnerability assessment and Setting SAIL adaptation implementation project funded by NOAA PSM grants)

A municipalities ***willingness to implement adaptation and resiliency actions*** often depends on their perceived risk and exposure to climate change impacts. In the case of Exeter, their climate risks are described below:

- Coastal impacts are limited to tidal and shoreland areas along the Squamscott River and Wheelwright Creek, a freshwater tributary. Assets at risk include several residential properties and businesses (<30), a senior housing facility, academic institution facilities (office building and boathouse), a section of state highway, and a limited number of local roadway segments.
- Inland riverine and isolated areas of flooding can be extensive during extreme rainfall events, tropical storms and hurricanes. Undersized and aging infrastructure are often damaged in these events and exacerbate flood related impacts.
- Winter blizzards and ice storms routinely cause widespread power outages and significant damage to roadside trees and forested areas.
- Changes in seasonal weather patterns have caused prolonged drought conditions in the recent past, resulting in implementation of townwide water bans and water conservations measures.

Although most of these impacts have been moderate, and some severe, in the past, the town is aware that ***impacts could escalate with changes in climate over the long term***. For this reason, Exeter is already taking steps to be resilient into the future including elevating their new wastewater treatment facility 2 feet above the 100-year/1% chance flood elevation and adopting their Climate Proclamation (to uphold the principles of the Paris Climate Accord).

Guided by a customized Climate Adaptation Policy, leadership from elected officials and decision makers, and strong support from community and civic groups, Exeter will be well positioned to tackle the challenges of climate change today and into the future.

7. SITE SELECTION AND BMP FEASIBILITY

A field assessment was performed at each of the locations shown in Figure 3 to determine the soil classification, seasonal high water table, nearby drainage infrastructure and controlling elevations, and feasibility for BMP retrofit. Soil coring was conducted on November 28th, and December 6th-7th, 2016 for Phase I and for Phase II and 9/22/2017. The site located behind Lincoln Street Elementary School (BMP4) was too gravelly to be cored and the soil type of that site was assumed to be urban fill with an infiltration rate based on the landform soil analysis given the geographic proximity and similarity in landform characteristics (e.g. slope). Landform soil mapping was done for eth watershed because the NRCS Web Soil Survey listed the entire area as urban disturbed soils. Land form mapping was conducted by mapping an adjacent subwatershed of similar features and slopes with soils series. Soil series were determined in a consistent manner based on slopes and confirmed by soil coring (Figure 6). With the exception of BMP 4 and 7, no seasonal high water table was observed,

Table 2.

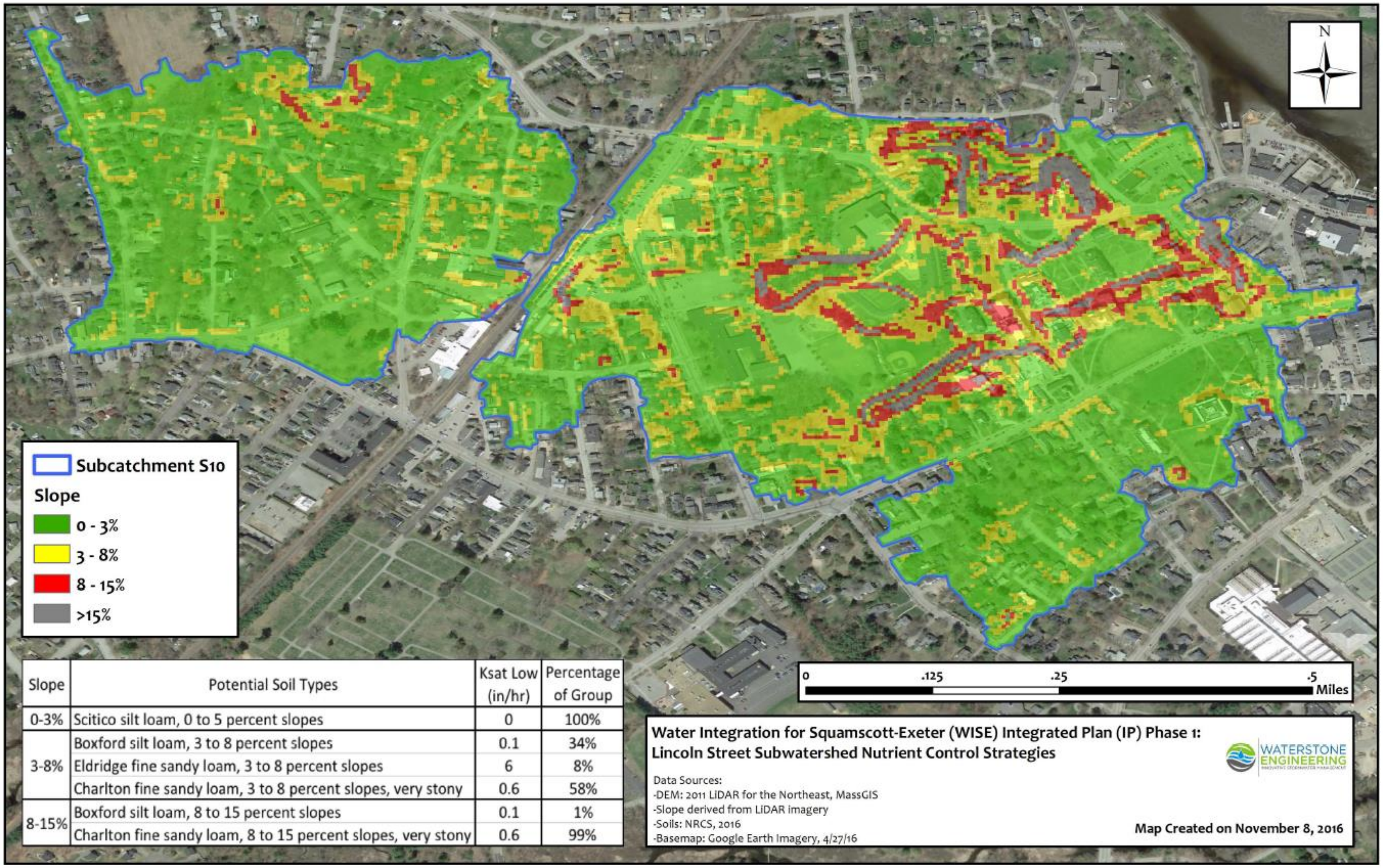
Soil cores indicated that all of the site are fine sandy loams with lower horizons as fine sands, hydrologic soil group B. The dominant soil type is a 62B: Charlton Fine Sandy Loam[9]. The soil samples from site 6 were more characteristic of a 33A: Scitico Silt Loam (hydrologic soil group C)[9] with largely clay and silt features below the upper horizon. Appendix E: Soil Test Pit Records describes each site's soil type, hydrologic soil group, published saturated hydraulic conductivity, and also contains a detailed field soil log.

Based on the physical characteristics of each site, a few suitable BMP types were identified. Subsurface infiltration systems with pre-treatment are applicable in parks or open space locations that have enough available area to house large storage chambers intended to divert flow from within the storm drain network and thereby treat large upstream drainage areas. ROW retrofits are applicable within the roadside right-of-way (ROW) and designed to treat surface runoff from roads and surrounding areas through connection into the existing drainage network. These systems can include tree planters, bioretention, and/or infiltration for stormwater treatment.

[9] SSSNNE (2009). Ksat Values for New Hampshire Soils - Special Publication No. 5. Durham, NH, Society of Soil Scientists of Northern New England; NRCS Web Soil Survey designation number and description

Table 2: Soil Core Results for Proposed BMP Locations

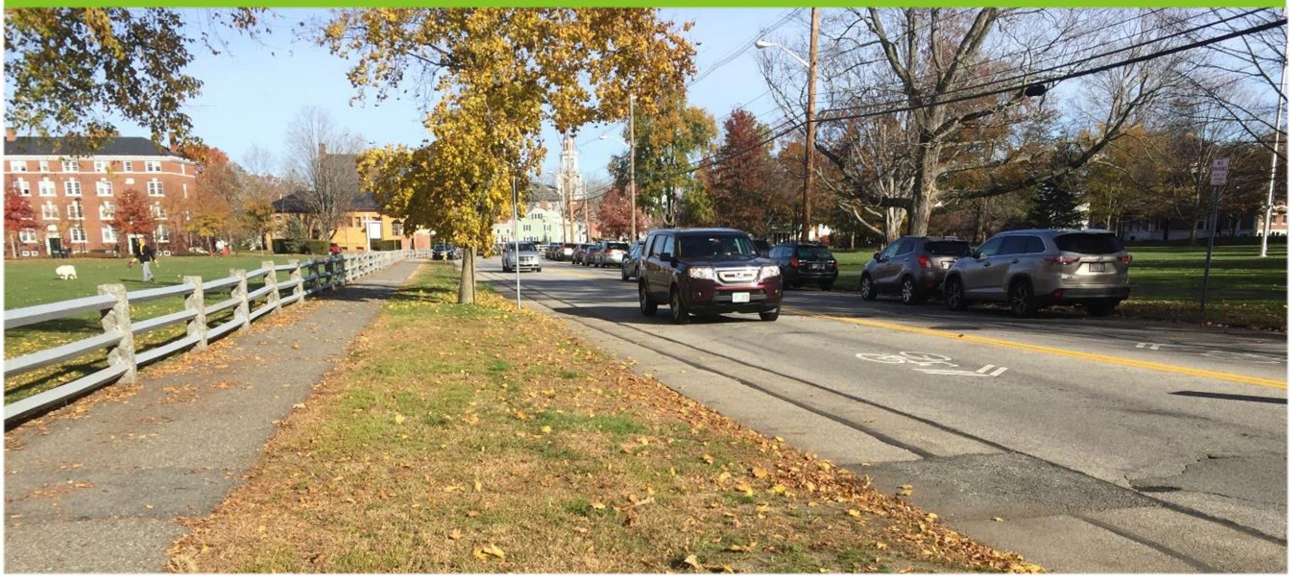
Name	Date	Technician	Location / Station	ESHWT	Max Depth / Refusal	Soil Horizons	Hydrologic Soil Group	Soil Series
TP1	11/28/2016	A. Moskal, M. Roseen	BMP2	Not Observed	60"	O: 0-4" A: 4-22" B: 22-42" C: 42"+	B	62B: Charlton Fine Sandy Loam, 3-8% Slopes
TP2	12/6/2016	A. Moskal, M. Roseen, J. Barry	BMP1	Not Observed	60"	O: 0-3" A: 3-8" B 8-35" C: 35"+	B	62B: Charlton Fine Sandy Loam, 3-8% Slopes
TP3	11/28/2016	A. Moskal, M. Roseen	BMP6	Not Observed	60"	O: 0-6" A: 6-12" B: 12"+	C	33A Scitico Silt Loam 0 to 5 % Slopes
TP4	12/6/2016	A. Moskal, M. Roseen, J. Barry	BMP3	Not Observed	60"	O: 0-2" A: 2-14" B: 14-32" C: 32"+	B	62B: Charlton Fine Sandy Loam, 3-8% Slopes
TP6	12/7/2016	A. Moskal	BMP5	Not Observed	60"	O: 0-2" A: 2-9" B: 9-28" C: 28"+	B	62B: Charlton Fine Sandy Loam, 3-8% Slopes
TP12, 13, 14	9/22/2017	T. Puls, R. Roseen	BMP 4	Not Observed	25+ inches	O: 0-2" A: 2-25"	C (assumed)	Urban Land, Boxford
TP15	9/22/2017	T. Puls, R. Roseen	BMP 7	53"	53 inches	O: 0-1" A: 1-6" B1: 6-12": B2 12-21": B3 21-51": C: 51-79"	B	62B: Charlton Fine Sandy Loam, 3-8% Slopes
TP10	9/22/2017	T. Puls, R. Roseen	BMP 8	Not Observed	87+ inches	O: 0-3" A: 3-20" B1: 20-32": B2 32-40": B3 40-60": C: 60"+	B	62B: Charlton Fine Sandy Loam, 3-8% Slopes
TP11	9/22/2017	T. Puls, R. Roseen	BMP 9	Not Observed	87+ inches	O: 0-2" A: 2-16" B1: 16-26": B2 26-50": B3 50-84": C: 84"+	B	62B: Charlton Fine Sandy Loam, 3-8% Slopes



Slope	Potential Soil Types	Ksat Low (in/hr)	Percentage of Group
0-3%	Scitico silt loam, 0 to 5 percent slopes	0	100%
3-8%	Boxford silt loam, 3 to 8 percent slopes	0.1	34%
	Eldridge fine sandy loam, 3 to 8 percent slopes	6	8%
	Charlton fine sandy loam, 3 to 8 percent slopes, very stony	0.6	58%
8-15%	Boxford silt loam, 8 to 15 percent slopes	0.1	1%
	Charlton fine sandy loam, 8 to 15 percent slopes, very stony	0.6	99%

Figure 6: Soil Mapping Based on Landform

8. BEST MANAGEMENT PRACTICE RETROFIT OPPORTUNITIES



For each of the locations discussed above, a feasibility analysis was performed based on location, upstream drainage area, and soil characteristics to determine its potential for a BMP retrofit. The location of BMPs focused on the feasibility of utilizing publicly controlled areas such as right-of-ways, parks, and open spaces.

Figure 3 depicts the eight sites within the watershed that were chosen for assessment. Ultimately, a suite of 18 BMPs were chosen for installation at sites, 1, 2, 3, 4, 5, 7, 8 and 9. Table 3 presents the BMP and upstream drainage area characteristics for these 18 BMPs.

a. Example Best Management Practices for Nutrient Control and Climate Resiliency

There are several best management practices that can be used in municipal, commercial, industrial, and residential areas to manage runoff from roof tops, impervious surfaces, and pervious surfaces. These include dry wells, subsurface infiltration systems, gravel wetlands, porous pavements, biofiltration, and high efficiency bioretention.

Figure 7 illustrates a tree planter installed as part of road reconstruction and sewer improvements. The tree planter combines a tree well and catchbasin with an engineered soil that provides a growing medium and water quality filter. The planter was designed with an eye towards low

Figure 7: Tree Planter Combined with Catch Basin

maintenance, especially during the winter. Tree planters like these can be cleared easily by snow plow and the sediment and debris removal process is limited to a deep sump and cleaning by vactor truck. With the tree planter grate the sidewalk area is usable for pedestrian travel.

Tree planters, bioretention, and other forms of infiltration or biofiltration can be combined with streetscapes for added functionality. Figure 8 shows a bioretention system located in a parking lot that could be applied in road right-of-way.

Figure 9 - Streetscape with Street Trees Adaptable for Stormwater Management

Figure 8: Parking Lot Bioretention

Figure 9 is an example of a streetscape and tree planter that could easily be combined for stormwater management. The street scape has a combination of pedestrian considerations, space for local business to use the sidewalks, and park benches, all of which could allow for use of some type of planter or infiltration system below ground.

Figure 10 shows a large scale subsurface infiltration system combined with an isolator row for pretreatment. The isolator row is a wrapped chamber that prevents clogging of the stone bed. A subsurface infiltration system such as this combined with a pretreatment design could be used effectively for flood control and nutrient reduction.

Figure 10: Subsurface Infiltration with Stone Reservoir and Isolator Row Pretreatment Chamber

Table 3 - BMP and Drainage Area Characteristics

Location	BMP #	BMP Type	Soil Type	Drainage Area (acres)	Annual TN Load (lbs)	System Size
WINTER STREET	1	Subsurface Infiltration	A	12.88	90.1	½" WQV
	2*	Subsurface Infiltration	A	24.56	157.6	½" WQV
LINCOLN STREET NORTH	3.1	Tree Planter	A	0.20	2.5	½" WQV
	3.2	Tree Planter	A	0.13	1.7	½" WQV
	3.3	Tree Planter	A	0.27	3.4	½" WQV
	3.4	Tree Planter	A	0.22	2.9	½" WQV
	3.5	ROW Infiltration- Grassed	A	0.24	2.4	½" WQV
	3.6	ROW Infiltration- Grassed	A	0.78	7.2	½" WQV
	3.8	ROW Infiltration- Grassed	A	1.20	9.1	½" WQV
	3.9	ROW Infiltration- Grassed	A	0.70	5.6	½" WQV
	3.22	ROW Infiltration- Grassed	A	0.20	1.3	½" WQV
LINCOLN STREET SOUTH	3.20	ROW Infiltration- Grassed	A	1.60	13.9	½" WQV
	3.21	ROW Infiltration- Grassed	A	0.24	1.4	½" WQV
LINCOLN STREET ELEMENTARY	4*	Subsurface Infiltration	D	32.43	255.3	½" WQV
FRONT STREET	5	Subsurface Infiltration	A	20.29	138.3	¼" WQV
LINCOLN STREET ELEMENTARY	7*	Subsurface Detention	A	7.41	58.1	0.15" WQV
FRONT STREET	8	Subsurface Infiltration	A	15.99	108.4	½" WQV
TAN LANE	9	Subsurface Infiltration	A	5.86	47.6	½" WQV
Totals	-	-	-	125.2	906.9	-

* Drainage area and Annual TN Load estimates exclude area and load managed by upstream BMPs

b. BMP 1: Subsurface Infiltration at the Intersection of Winter and Front Street

BMP 1 was chosen for full 95% design and costing. It is located in a public playground at the intersection of Winter Street and Front Street (Figure 11). Soils test pits within this site identified fine sandy loams that are highly suitable for infiltration as they fall in hydrologic soil group A. The project team assessed the impacts of installing a subsurface infiltration treatment system to manage the 13-acre upstream drainage area.

Figure 11: BMP 1 Subsurface Infiltration at the Intersection of Winter and Front Street

Subsurface infiltration systems of several sizes were modeled to compare the costs of construction against the nutrient loading and flood reduction benefits. The three sizes that were considered were a ¼" water quality volume system (big enough to fully capture the 1^{st} ¼" of runoff from the upstream drainage area), a ½" WQV system, and a 'flood sized' system big enough to capture runoff from an event slightly smaller than the 2-year storm (this was the maximum potential size based on the proposed site).

Ultimately, it was decided that the ½" WQV system would provide the most benefit relative to the associated costs. This BMP is expected to manage 68.2 lbs of nitrogen annually, leading to a 76% load reduction from the upstream drainage area at a total cost of $45,900. It will also reduce flooding extent and duration downstream during large storm events, including along Railroad Avenue. Figure 12 shows the 95% engineering design for BMP 1.

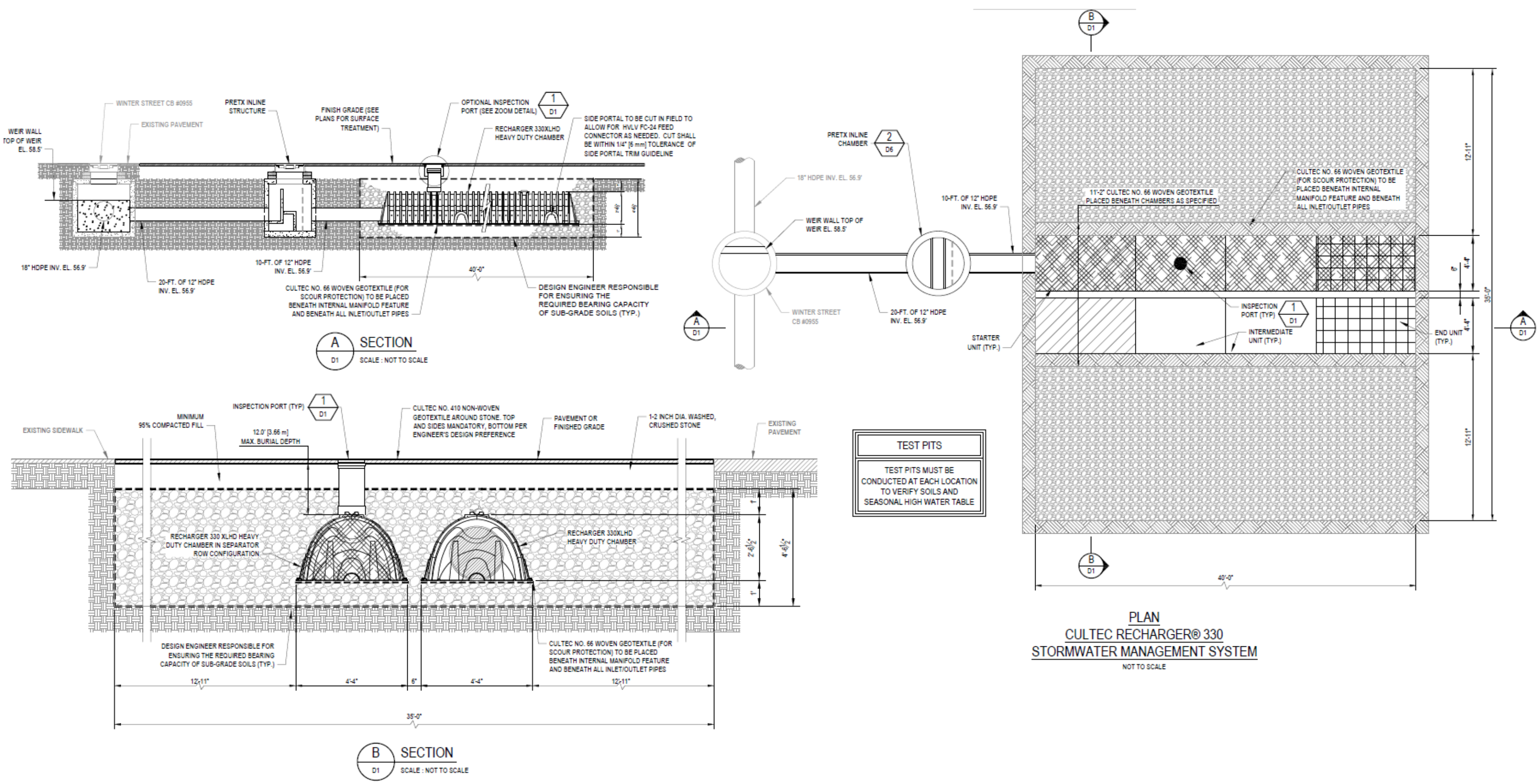


Figure 12: Engineering Detail for Winter Street Subsurface Infiltration BMP 1

c. BMP 2: Subsurface Infiltration at Columbus Ave., Winter St., Railroad Ave. Intersection

BMP 2 was chosen for full 95% design and costing. It is located in a small park at the intersection of Columbus Avenue, Winter Street, and Railroad Avenue (Figure 13). The project team assessed the impacts of installing a subsurface infiltration system to manage the 25-acre upstream drainage area. Soil test pits within this site found fine sandy loams highly suitable for infiltration as they fall in hydrologic soil group A. Some reconfiguration of the drainage infrastructure would be required to divert flows and is described in Appendix A: Factsheets.

.

Figure 13: BMP 2 Subsurface Infiltration Site at the Intersection of Columbus Ave., Winter St., and Railroad Ave.

Subsurface infiltration systems of several sizes were modeled to compare the costs of construction against the nutrient loading and flood reduction benefits. The three sizes that were considered were a ¼" water quality volume system (big enough to fully capture the 1st ¼" of runoff from the upstream drainage area), a ½" WQV system, and a 'flood sized' system of the maximum potential size based on the proposed site.

Ultimately, it was decided that the ½" WQV system would provide the most benefit relative to the associated costs. This BMP is expected to manage 120.2 lbs of nitrogen annually, leading to a 76% load reduction from the upstream drainage area at a total cost of $79,000. It will also reduce flooding extent and duration downstream during large storm events, including along Railroad Avenue. Figure 14 shows the 95% engineering design for BMP 2.

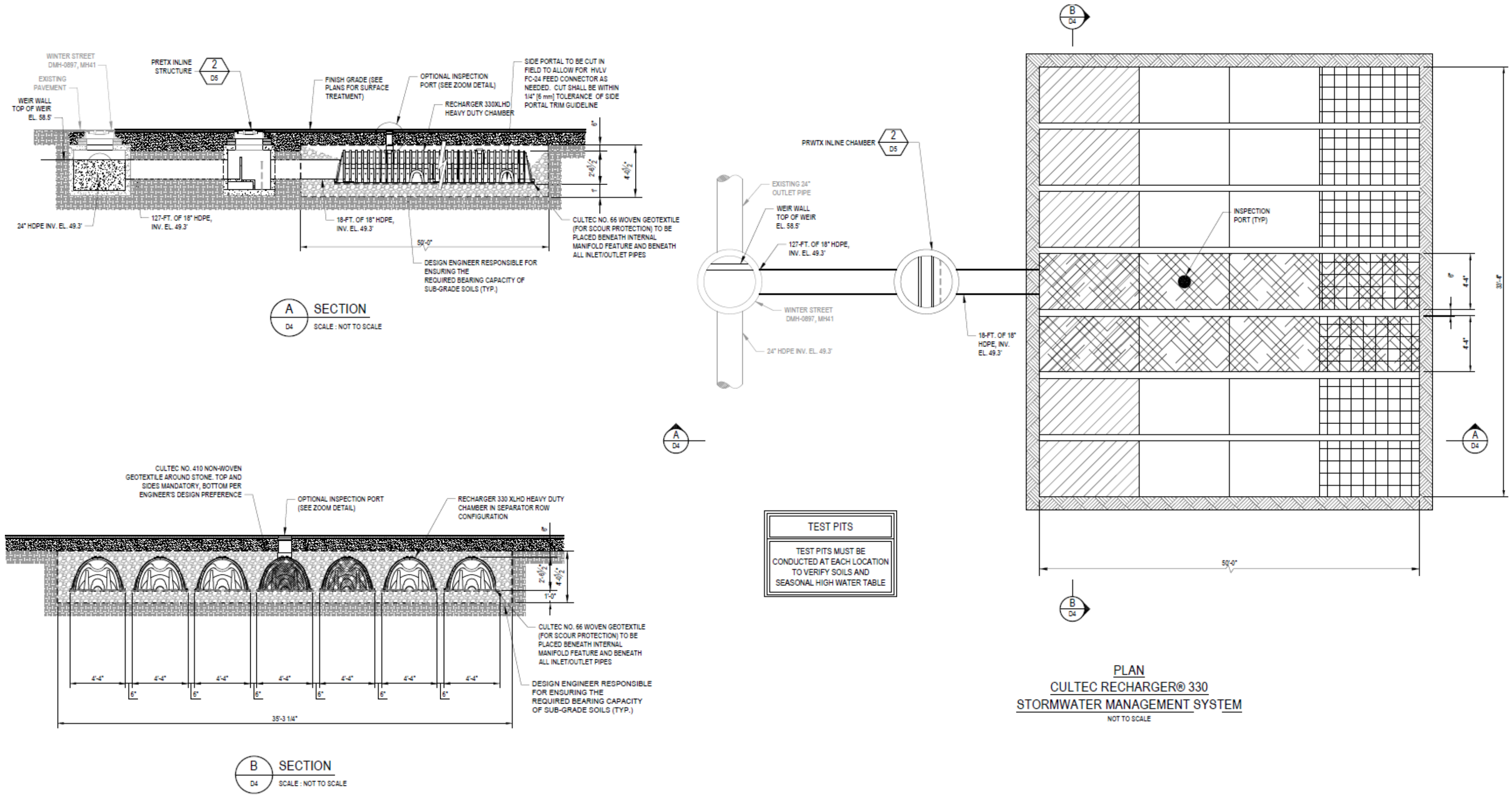


Figure 14: Engineering Detail for Railroad Avenue Subsurface Infiltration BMP 2

d. BMP 3: ROW Infiltration on Lincoln Street

BMP 3 was chosen for full 95% design and costing. It consists of numerous (11) small systems located in the public right-of-way on Lincoln Street. These BMPs will be a mix of tree planters and right-of-way infiltration systems located in the public right-of-way. These BMPs would manage surface and road runoff from 5.8 acres (Figure 15). Soils within this site are fine sandy loams and are highly suitable for infiltration as they fall in hydrologic soil group A.

Figure 15: BMP 3 ROW Infiltration Site on Lincoln Street

ROW infiltration systems of several sizes were modeled to compare the costs of construction against the nutrient loading and flood reduction benefits. The three sizes that were considered were a ¼" water quality volume system (big enough to fully capture the 1st ¼" of runoff from the upstream drainage area), a ½" WQV system, and a 'flood sized' system of the maximum potential size based on the proposed site.

Ultimately, it was decided that the ½" WQV systems would provide the most benefit relative to the associated costs. These BMPs are expected to manage 39.6 lbs of nitrogen annually, leading to a 77% load reduction from the upstream drainage area at a total cost of $139,700. It will also reduce flooding extent and duration downstream during large storm events. Figure 16 and Figure 17 show the 95% engineering designs for BMPs 3.1-3.22.

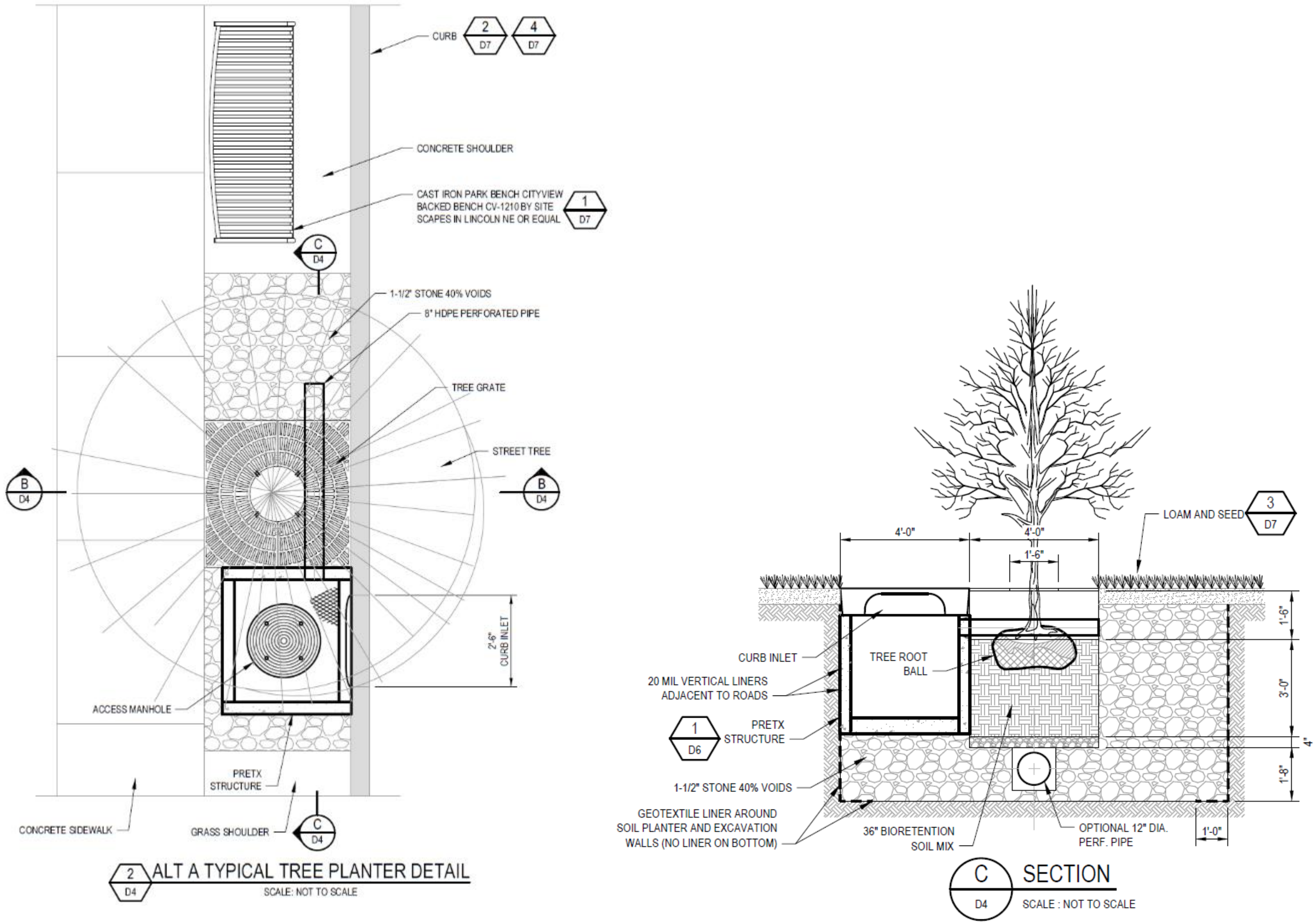
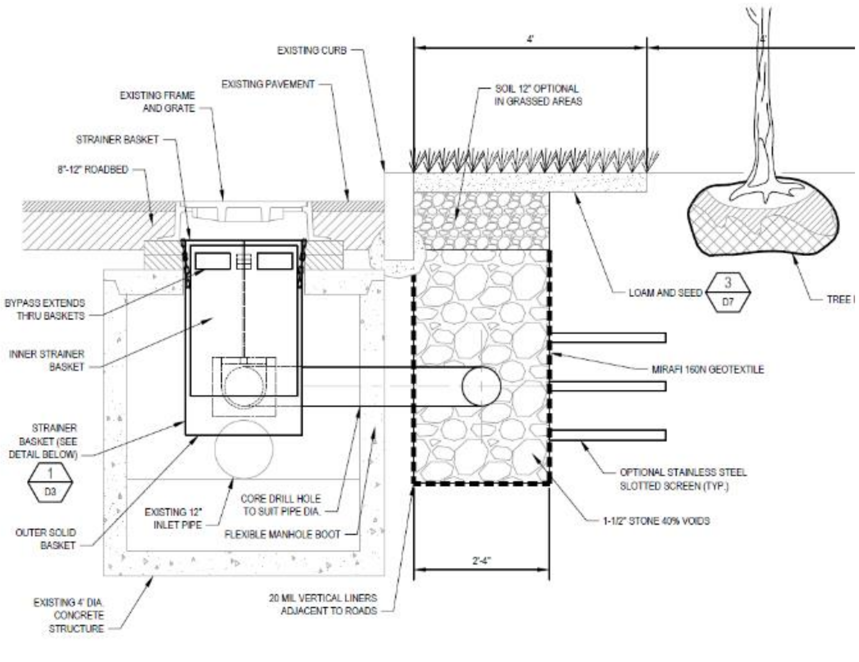
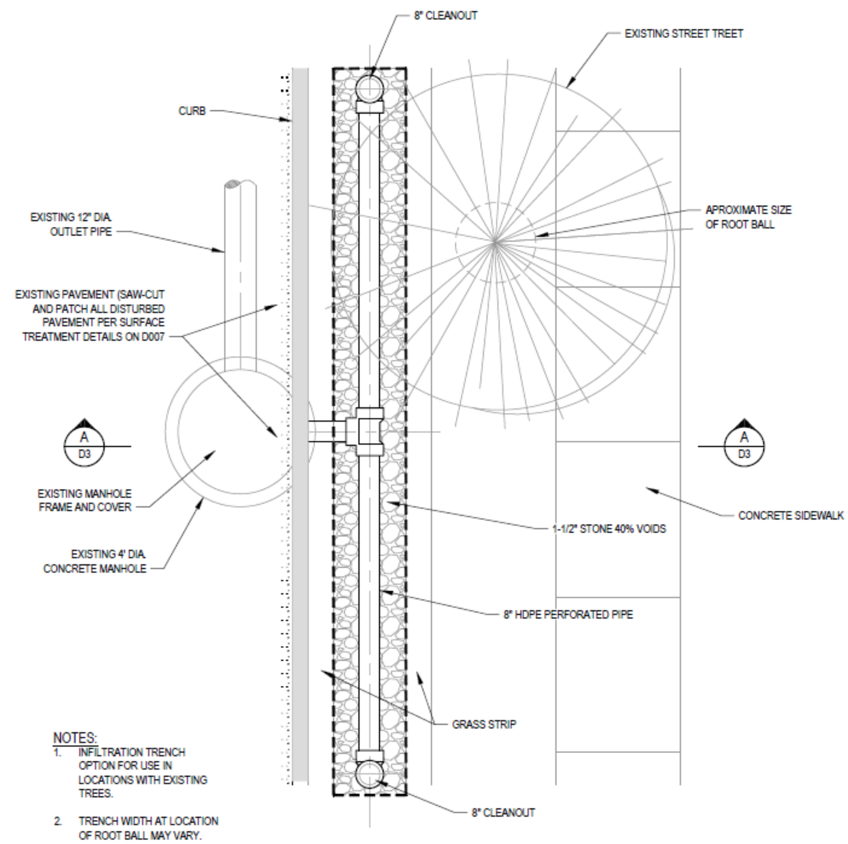


Figure 16: Engineering Detail for Lincoln Street North, Tree Planter BMPs 3.1 -3.4



RIGHT-OF-WAY RETROFIT DETAIL

SCALE: NOT TO SCALE



ALT B TYPICAL TREE TRENCH INFILTRATION DETAIL

SCALE: NOT TO SCALE

Figure 17: Engineering Detail for Lincoln Street South Right-of-Way Infiltration BMPs 3.5, 3.6, 3.8, 3.9, 3.20, 3.21, 3.22

e. BMP 4: Subsurface Infiltration at Lincoln Street Elementary School Parking Lot Revised

BMP 4 was chosen for 75% design and costing as part of the Phase II analysis. The proposed site for BMP 4 is located behind the Lincoln Street Elementary School parking lot (Figure 18). The entire upstream drainage area is 76 acres, which would be reduced to 33 acres with the installation of BMPs 1, 2, and 3. Soils within this site are fine sandy loams and are suitable for infiltration however there is a shallow depth to groundwater that would need to be further evaluated. Given the size of the usable area it is feasible to install a very large subsurface infiltration or detention system within this site capable of providing storage and flood mitigation.

Figure 18: BMP 4 Subsurface Infiltration Site Behind the Lincoln Street Elementary School Parking Lot

Subsurface infiltration systems of several sizes were modeled to compare the costs of construction against the nutrient loading and flood reduction benefits. The three sizes that were considered were a ¼” water quality volume system (big enough to fully capture the 1^{st} ¼” of runoff from the upstream drainage area), a ½” WQV system, and a ‘flood sized’ system big enough to capture runoff from an event slightly smaller than the 2-year storm (this was the maximum potential size based on the proposed site).

Ultimately, it was decided that the ½” WQV system would provide the most benefit relative to the associated costs. This BMP is expected to manage 230 lbs of nitrogen annually, leading to a 90% load reduction from the upstream drainage area at a total cost of $260,000. It will also reduce flooding extent and duration downstream during large storm events.

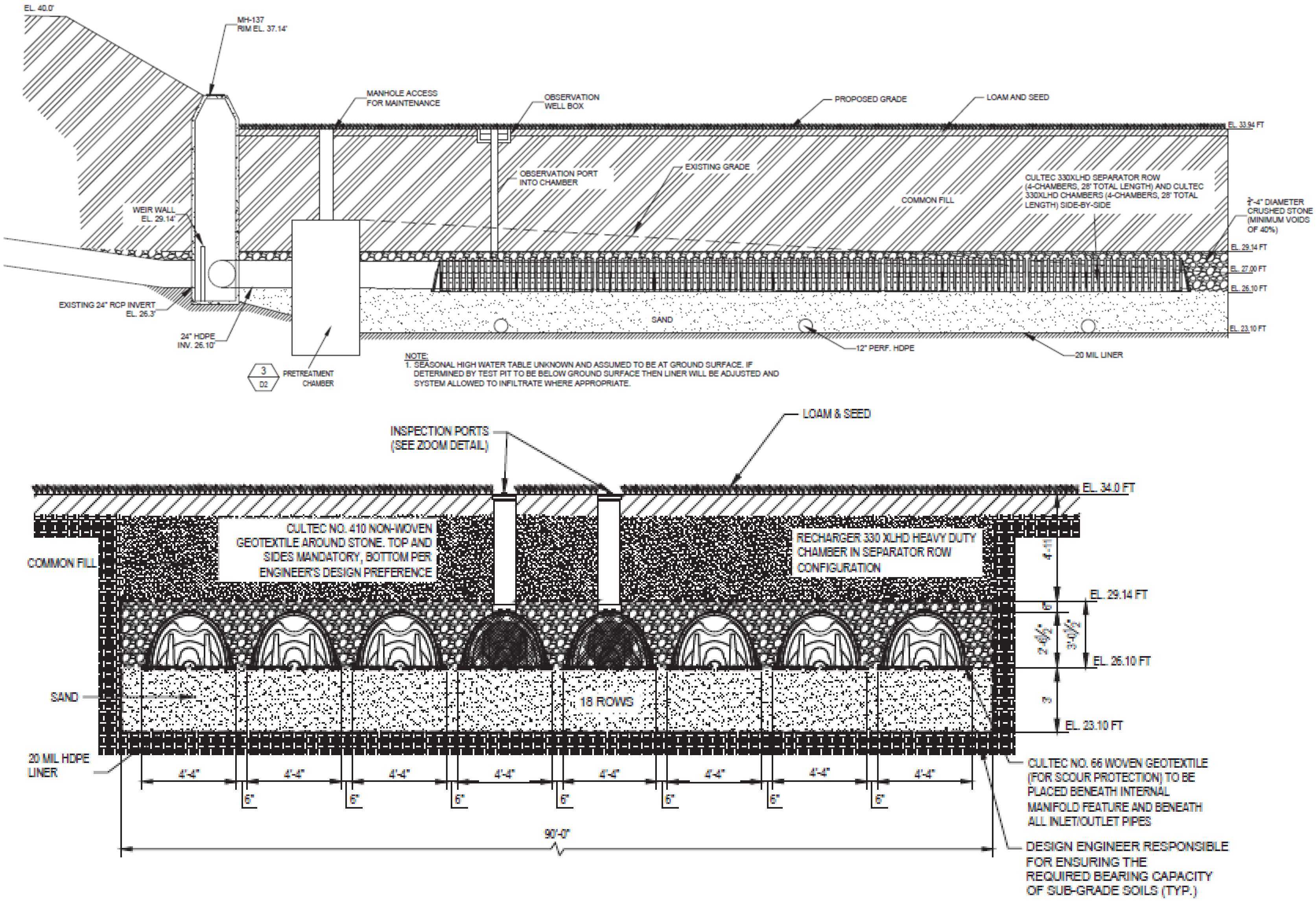


Figure 19: Engineering Section Details for Subsurface Infiltration BMP 4

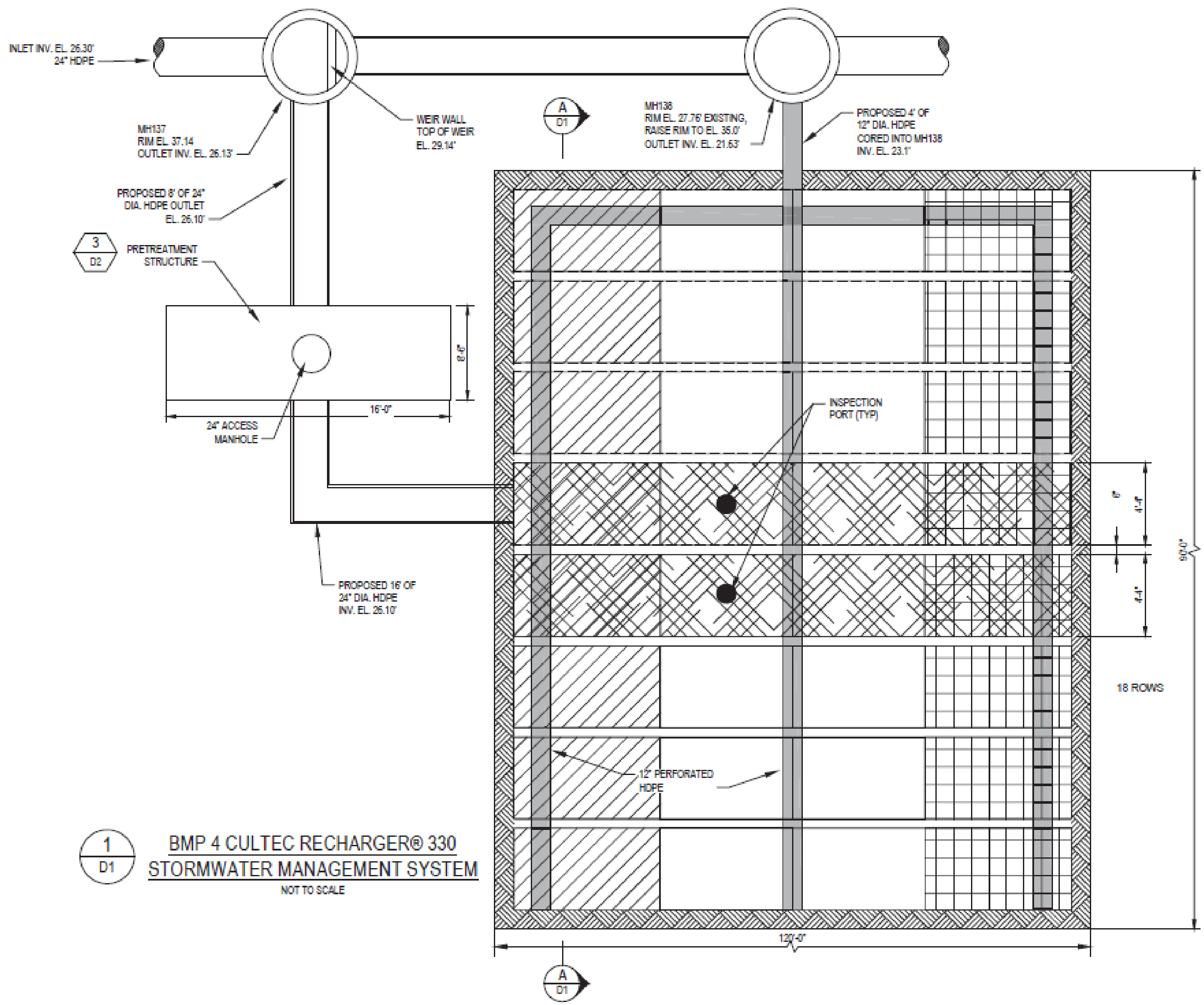


Figure 20: Engineering Plan View Detail for Subsurface Infiltration BMP 4

f. BMP 5: ROW Infiltration/Filtration on Front Street

BMP 5 was chosen for full 95% design and costing. It is located in the public right-of-way on Front Street in front of Philips Exeter Academy (Figure 21). Soils within this site are fine sandy loams and are highly suitable for infiltration. The project team assessed the impacts of installing a subsurface infiltration treatment system to manage the 20-acre upstream drainage area.

Figure 21: BMP 5 ROW Infiltration/Filtration Site on Front Street

Subsurface infiltration systems of several sizes were modeled to compare the costs of construction against the nutrient loading and flood reduction benefits. The three sizes that were considered were a ¼" water quality volume system (big enough to fully capture the 1st ¼" of runoff from the upstream drainage area), a ½" WQV system, and a 'flood sized' system of the maximum potential size based on the proposed site.

Ultimately, it was decided that the ¼" WQV system would provide the most benefit relative to the associated costs. This BMP is expected to manage 71.7 lbs of nitrogen annually, leading to a 52% load reduction from the upstream drainage area at a total cost of $45,200. It will also reduce flooding extent and duration downstream during large storm events. Figure 22 shows the 95% engineering designs for BMP 5.

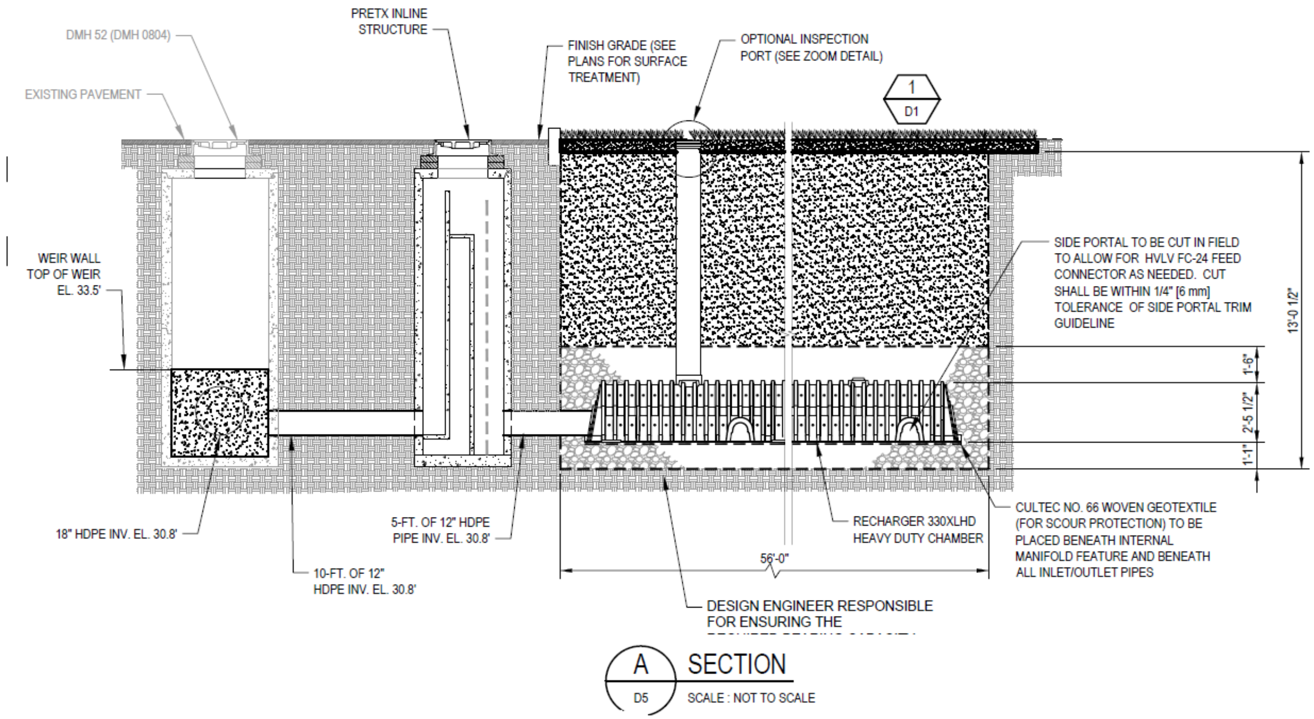


Figure 22: Engineering Section Detail for Front Street Subsurface Infiltration BMP 5

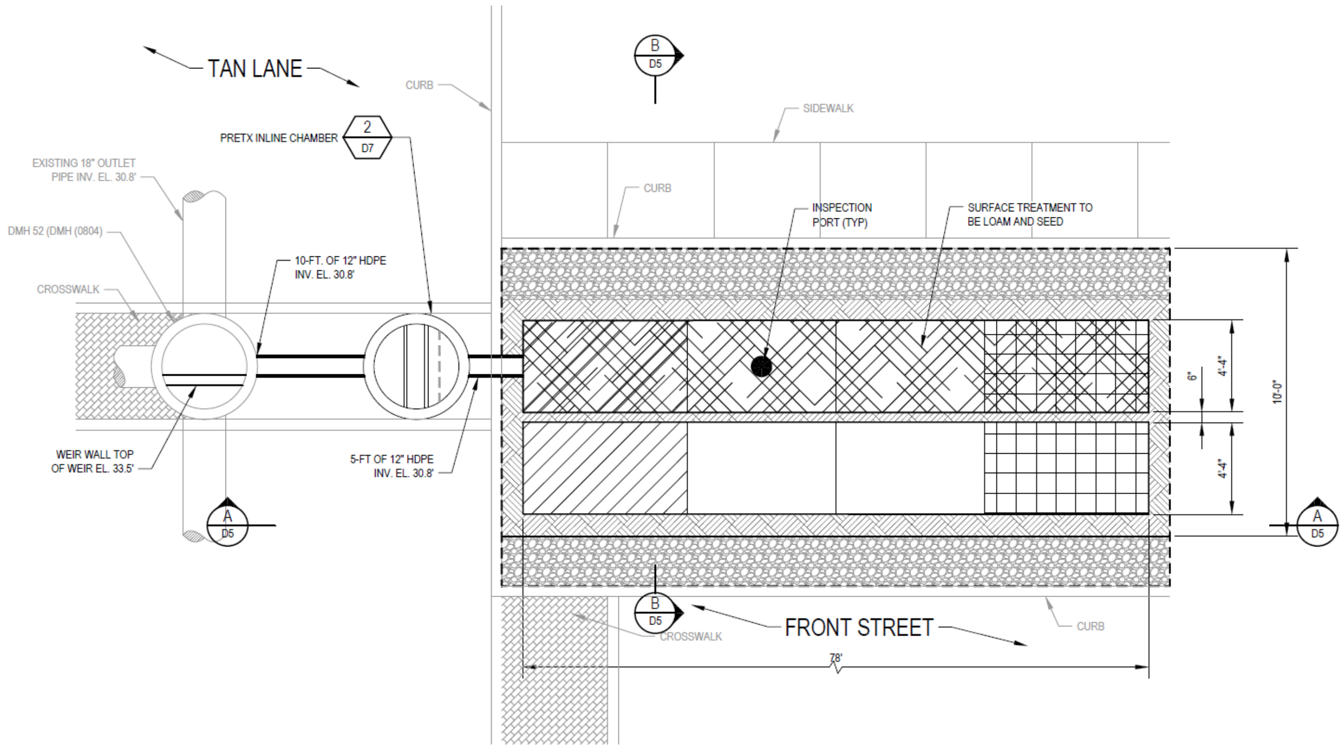


Figure 22: Engineering Plan View Detail for Front Street Subsurface Infiltration BMP 5

g. BMP 7: Subsurface Infiltration in the Lincoln Street Elementary School Fields

BMP 7 was chosen for 75% design and costing as part of the Phase II analysis. The proposed site for BMP 7 is located behind the Lincoln Street Elementary School in a large grassed area (Figure 23). Soil cores were conducted to shallow depths of 25" only due to the nature of the urban fill and large rocks. Soil type was assumed to hydrologic soil group C, Scitico sandy clay loam based on land form mapping. Given the size of the usable area, it could be feasible to install a large subsurface detention treatment system within this site with 29 acres of upstream drainage area, reduced to 7.4 acres after installation of BMPs 1, 2, and 3.

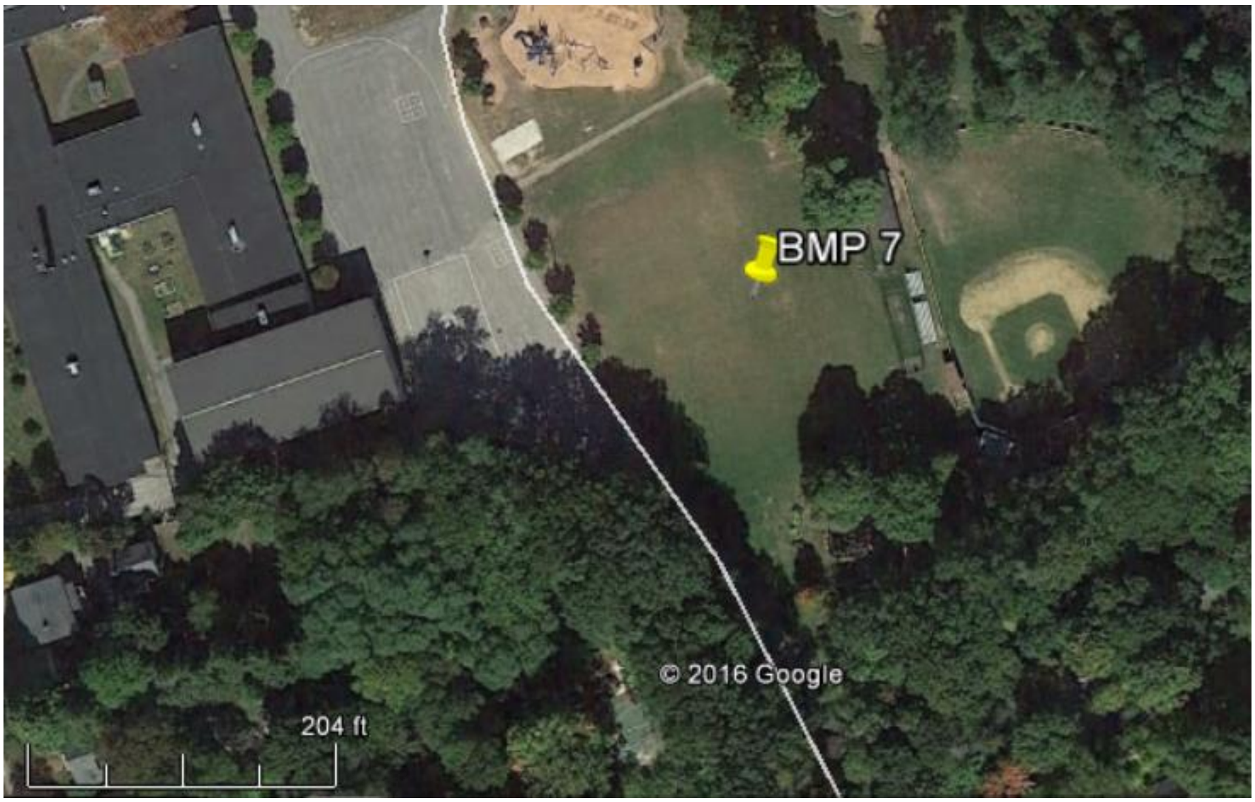


Figure 23: BMP 7 Subsurface Infiltration at Lincoln Street Elementary School

Subsurface detention systems of several sizes were modeled to compare the costs of construction against the nutrient loading and flood reduction benefits. The three sizes that were considered were a 0.15" water quality volume system (big enough to fully capture the 1st 0.15" of runoff from the upstream drainage area), a ½" WQV system, and a 'flood sized' system big enough to capture runoff from an event slightly smaller than the 2-year storm (this was the maximum potential size based on the proposed site).

Ultimately, it was decided that the 0.15" WQV system would provide the most benefit relative to the associated costs. This BMP is expected to manage 7 lbs of nitrogen annually, leading to a 12% load reduction from the upstream drainage area at a total cost of $33,000. It will also reduce flooding extent and duration downstream during large storm events.

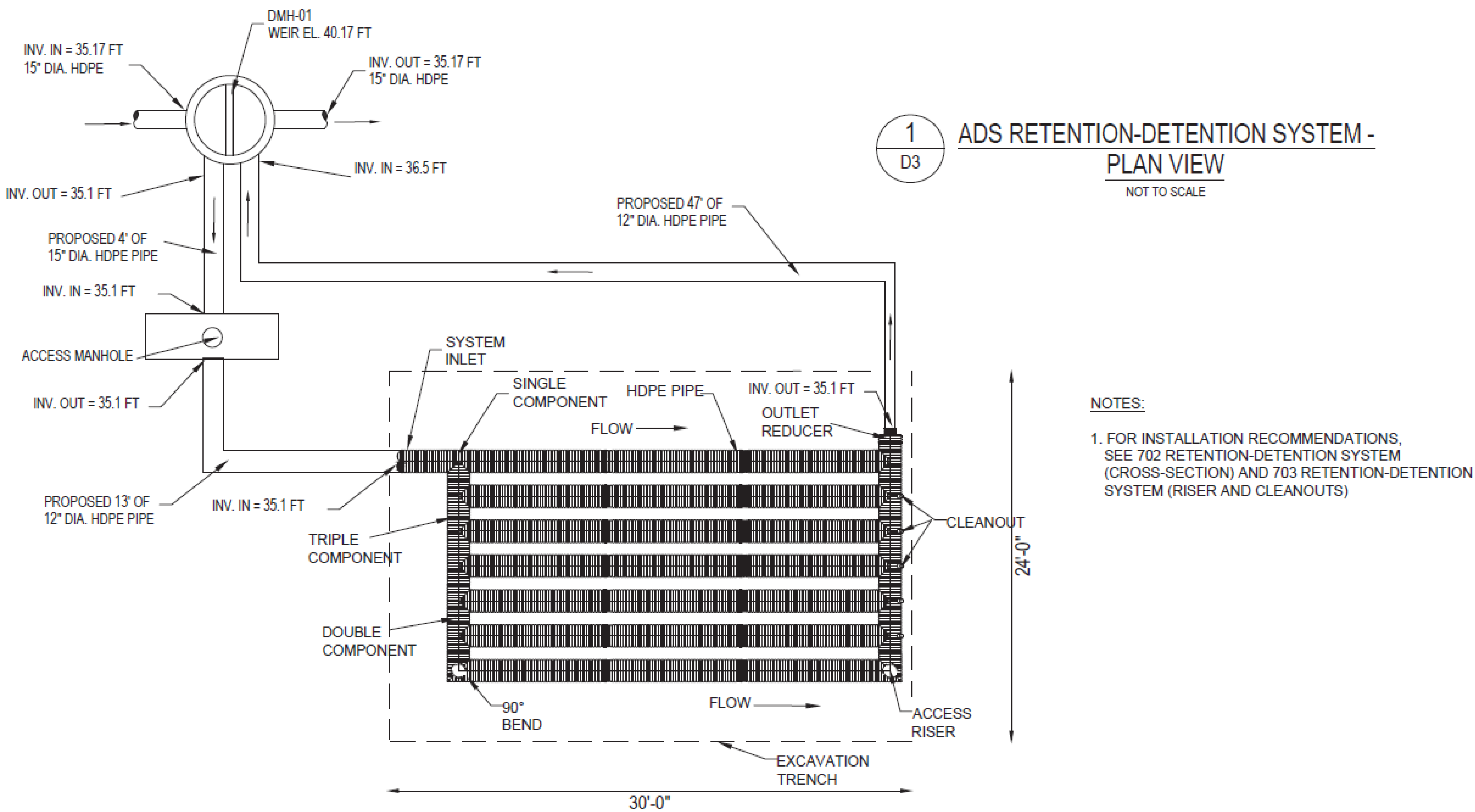


Figure 24: Engineering Detail for Subsurface Detention System BMP 7

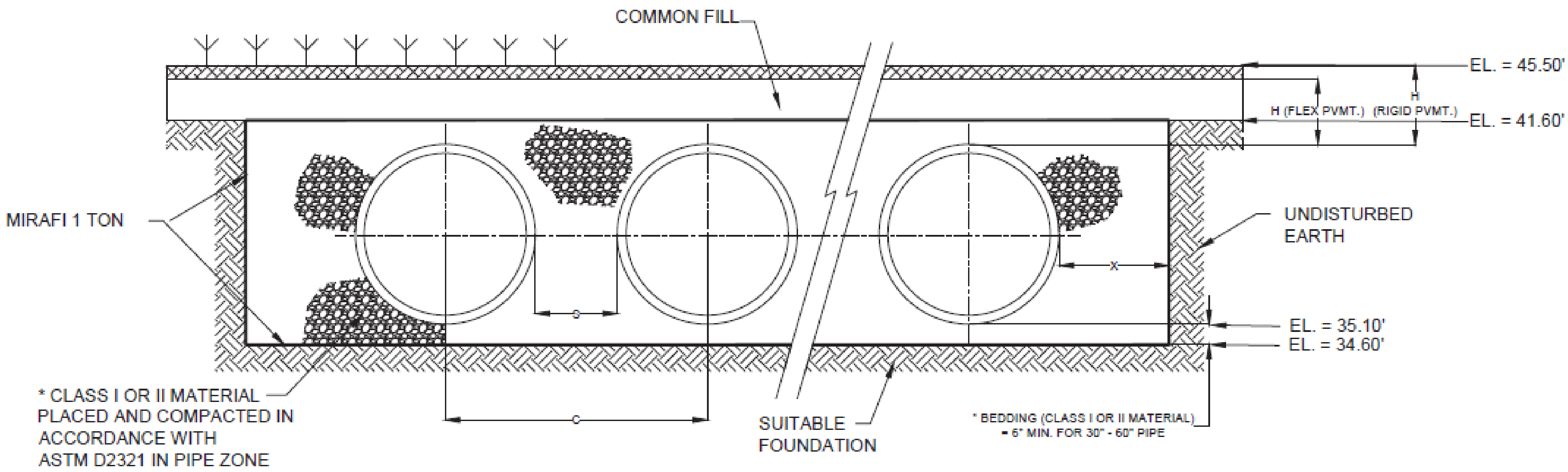


Figure 25: Engineering Detail for Subsurface Detention System BMP 7

h. BMP 8: ROW Infiltration/Filtration on Elm Street

BMP 8 was chosen for 75% design and costing as part of Phase 2. It is located in the public right-of-way on the corner of Front Street and Elm Street (Figure 26). Soils within this site are fine sandy loams and are highly suitable for infiltration. The project team assessed the impacts of installing a subsurface infiltration treatment system to manage the 16-acre upstream drainage area.

Figure 26: BMP 8 ROW Infiltration/Filtration Site on Elm Street

Subsurface infiltration systems of several sizes were modeled to compare the costs of construction against the nutrient loading and flood reduction benefits. The three sizes that were considered were a ¼" water quality volume system (big enough to fully capture the 1st ¼" of runoff from the upstream drainage area), a ½" WQV system, and a 'flood sized' system of the maximum potential size based on the proposed site.

Ultimately, it was decided that the ½" WQV system would provide the most benefit relative to the associated costs. This BMP is expected to manage 107 lbs of nitrogen annually, leading to a 99% load reduction from the upstream drainage area at a total cost of $53,500. It will also reduce flooding extent and duration downstream during large storm events. Figure 28 shows the 75% engineering designs for BMP 8.

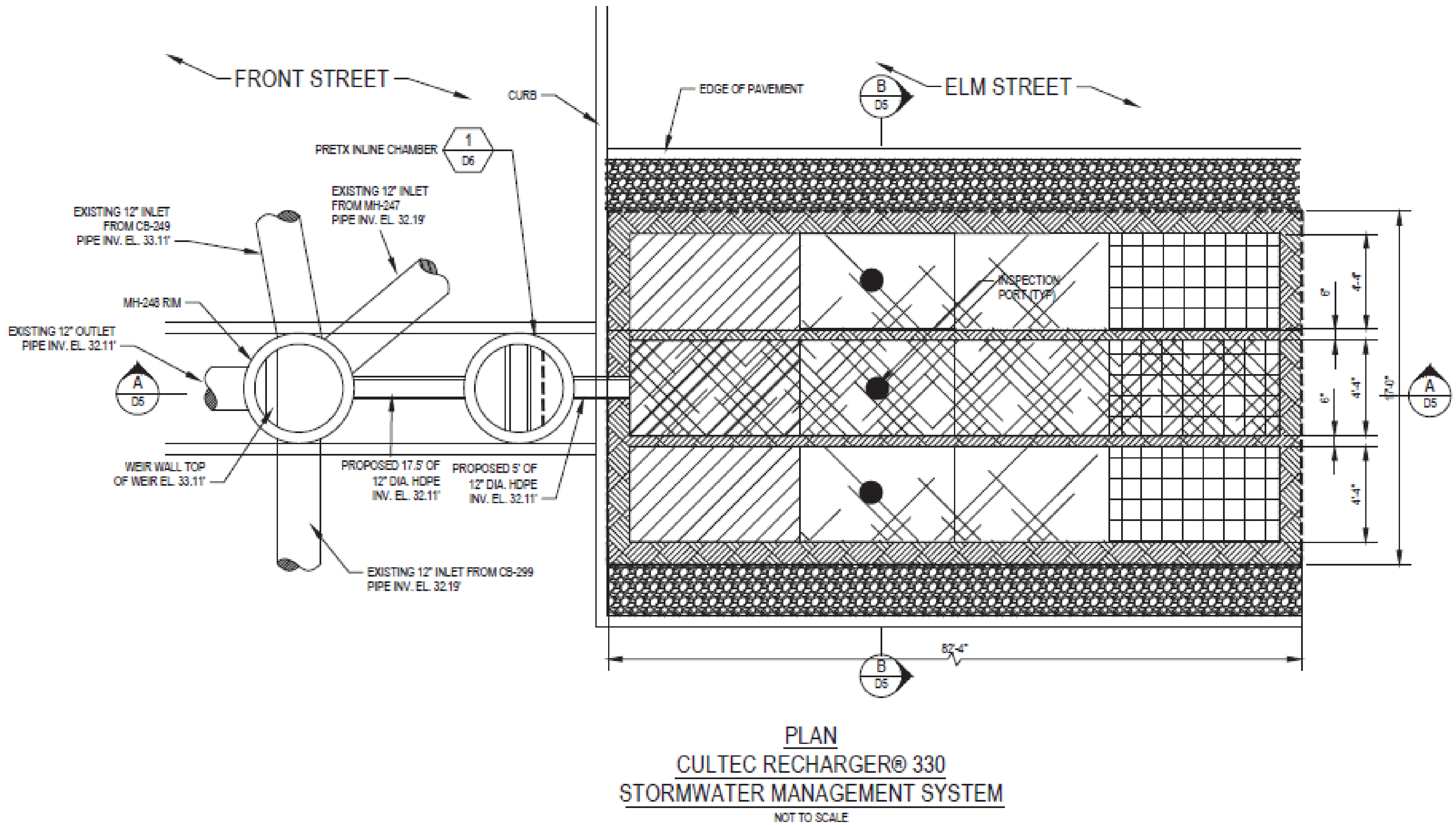


Figure 27: Engineering Layout Detail for Subsurface Infiltration System BMP 8

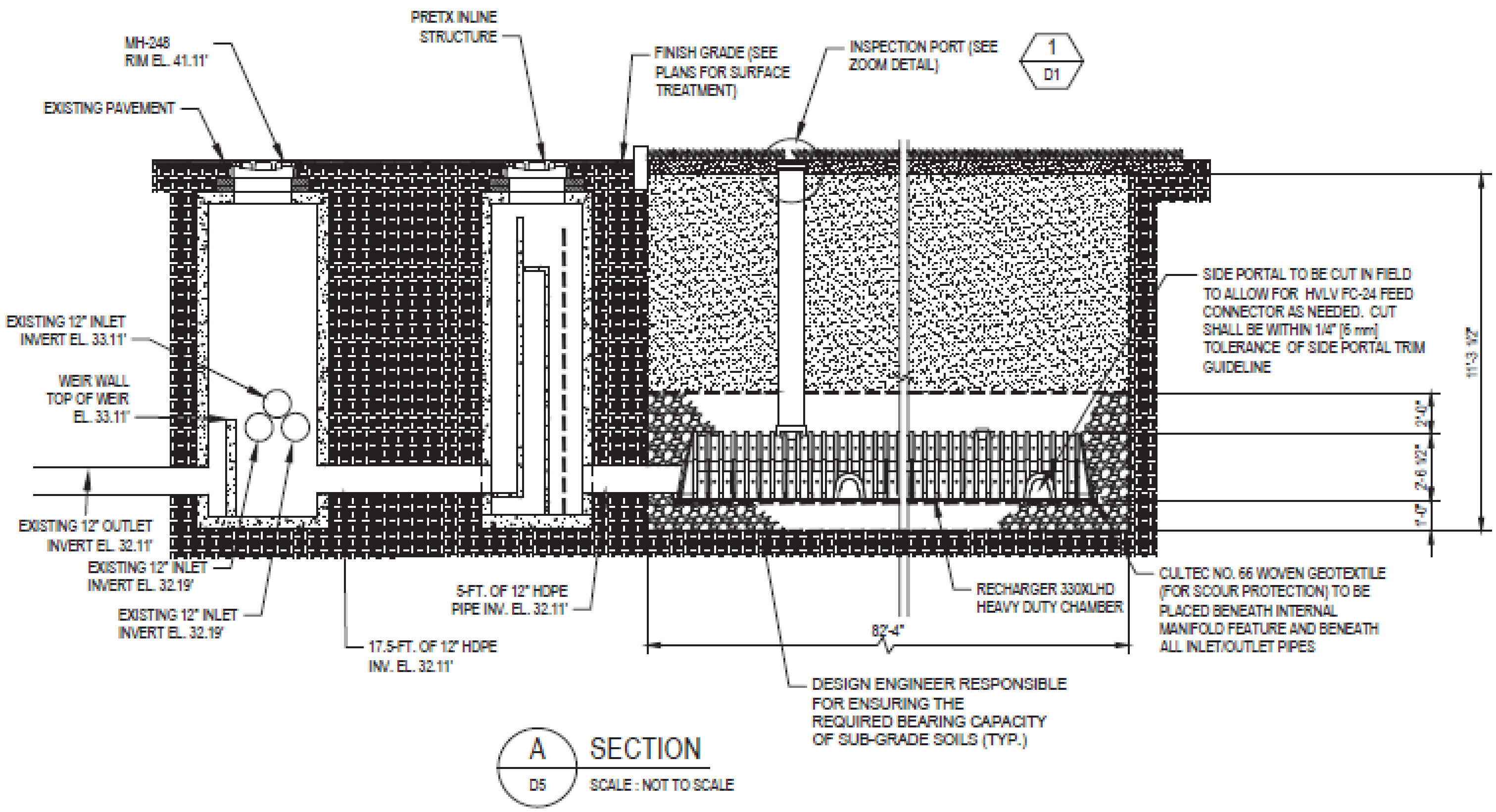


Figure 28: Engineering Section Detail for Subsurface Infiltration System BMP 8

i. BMP 9: ROW Infiltration/Filtration on Tan Street

BMP 9 was chosen for 75% design and costing as part of Phase 2. It is located in the public right-of-way on the corner of Main Street and Tan Lane (Figure 29). Soils within this site are fine sandy loams and are highly suitable for infiltration. The project team assessed the impacts of installing a subsurface infiltration treatment system to manage the 6-acre upstream drainage area.

Figure 29: ROW Infiltration/Filtration on Tan Lane

Subsurface infiltration systems of several sizes were modeled to compare the costs of construction against the nutrient loading and flood reduction benefits. The three sizes that were considered were a ¼" water quality volume system (big enough to fully capture the 1st ¼" of runoff from the upstream drainage area), a ½" WQV system, and a 'flood sized' system of the maximum potential size based on the proposed site.

Ultimately, it was decided that the ½" WQV system would provide the most benefit relative to the associated costs. This BMP is expected to manage 47 lbs of nitrogen annually, leading to a 99% load reduction from the upstream drainage area at a total cost of $33,600. It will also reduce flooding extent and duration downstream during large storm events. Figure 31 shows the 75% engineering designs for BMP 9.

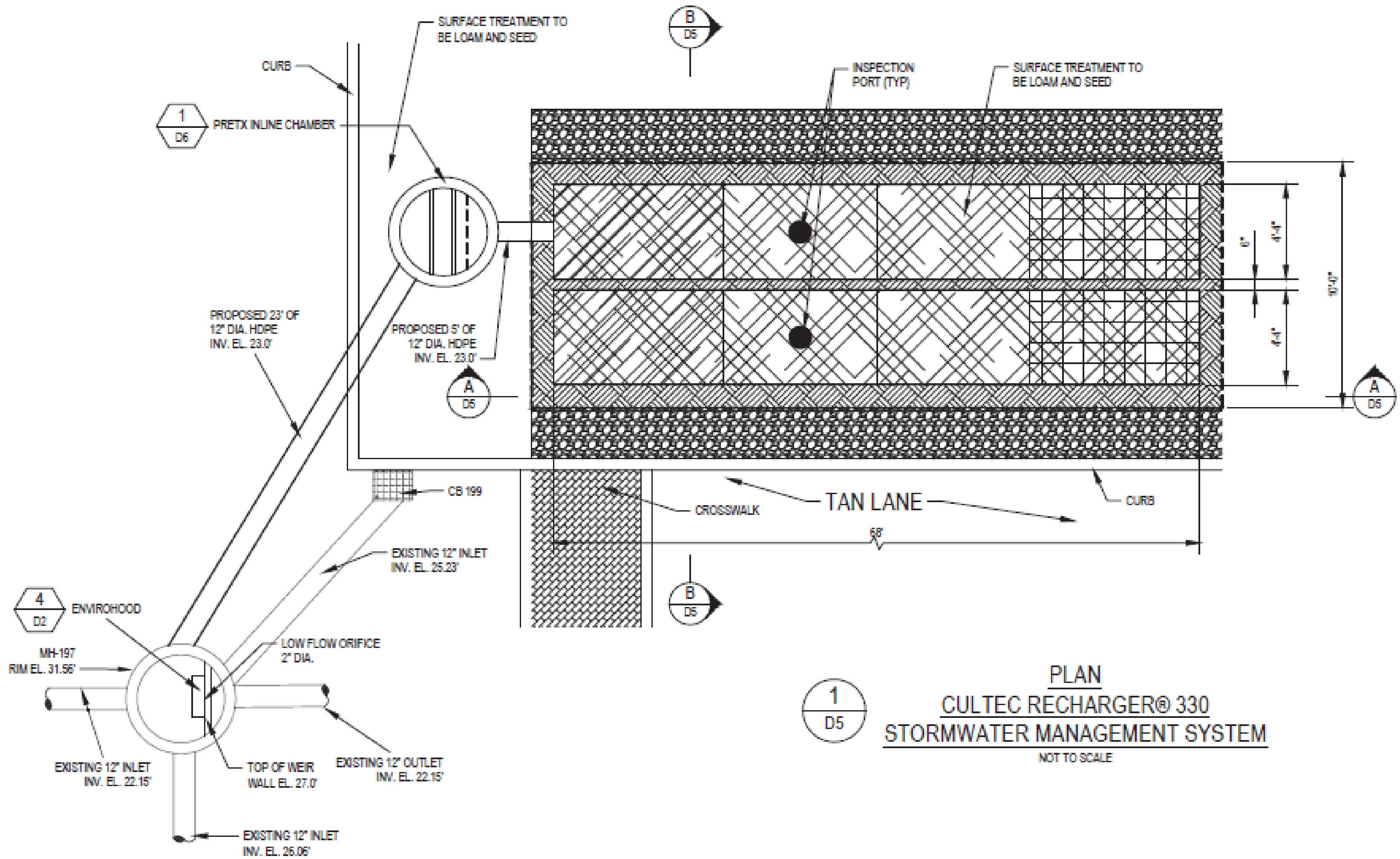


Figure 30: Engineering Plan View Detail for Subsurface Infiltration System BMP 9

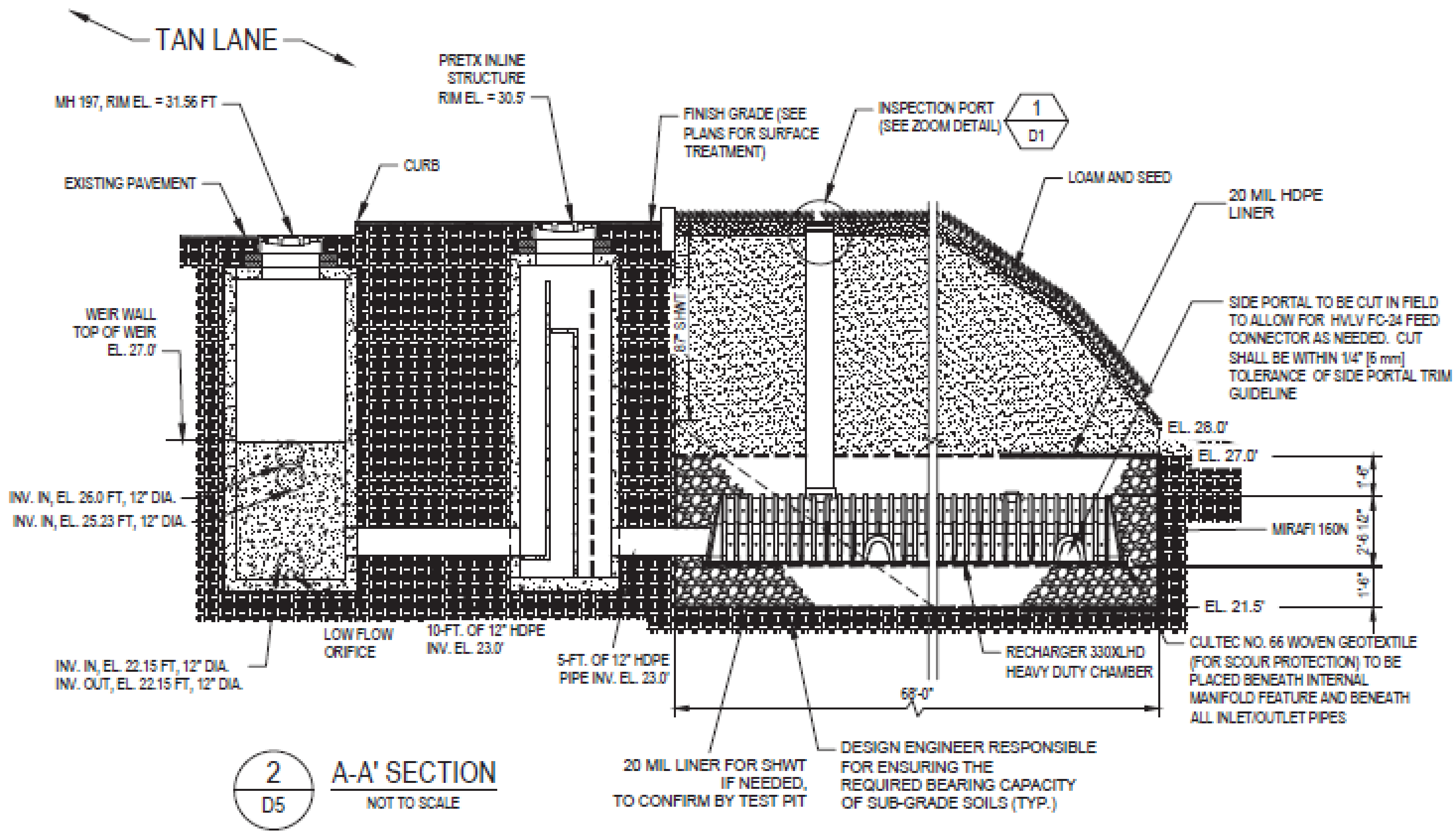


Figure 31: Engineering Section Detail for Subsurface Infiltration System BMP 9

j. BMP Optimization and Lowest Cost Option

One of the core elements of integrated planning is the allowance that a permittee can take credit for actions associated with one permit (i.e., wastewater) while simultaneously receiving credit under another (i.e., MS4). For example, installation of green infrastructure (i.e., biofiltration to treat road runoff, or drywells to treat runoff from roof tops) for non-point source management under the WWTF permit would also satisfy requirements for Post Construction Stormwater Management (Minimum Measure 5) in the 2017 NH Small MS4 permit. This has the potential to be more economical than traditional permitting because it satisfies elements of both the MS4 and wastewater permits and it helps manage the uncertainty of environmental response.

Integrated planning also allows for flexibility as to when and what runoff management measures are implemented so long as the goal is the protection of public health and water quality. This approach allows for the use of various sizes (i.e., capture depths) of BMPs to allow for a greater number of smaller systems in replace of fewer systems designed to treat larger volumes.

An optimization model was developed as part of WISE which selects the most cost effective management measures for a range of runoff reduction levels. The optimization model runs iteratively, changing the target volume reduction with each iteration. It evaluates the runoff control strategies based upon user defined constraints including available land for implementation, volume reduction capability based on capture depth of the BMP, and cost to implement the strategy. This is first applied at the system level to develop a series of BMP performance curves. It is next applied at the land use scale to identify the most cost effective options for each particular land use. The optimization is then conducted at the watershed scale for the range of available runoff control measures, given the range of land uses within the wastershed. Appendix H: Pollutant Load Methodology presents BMP optimization and costing examples.

9. WATERSHED ANALYSIS

a. Vulnerability Analyses

This section provides a summary of the methodology behind the water quality and hydrologic and hydraulic stormwater runoff model ("Model") for the Town of Exeter storm drainage infrastructure, initially developed as part of the Climate Adaptation Plan for Exeter (CAPE) project and WISE pollutant load model, and updated as part of this effort. A more in-depth description can be found in Appendix F: Watershed Modeling of this document. The Model was created using the US Environmental Protection Agency (USEPA) Storm Water Management Model (SWMM) modeling platform to evaluate water quality and flooding potential of the stormwater infrastructure network under varying storm depths and future buildout conditions. The Model was used to investigate the flooding and surcharging of town storm drainage infrastructure during the 10-yr, 24-hr design storm (event depth of 4.72")[10]. The Model was created for planning purposes and includes some simplifying assumptions; it is not intended to provide design parameters for stormwater infrastructure installation and/or replacement. The preliminary stormwater infrastructure designs prepared for the Town of Exeter included independent detailed hydraulic/hydrologic analysis. Detailed information is provided in Appendix F: Watershed Modeling.

BMP designs and associated modeling calculations were performed with the HydroCAD (v 9.1) software package. Hydrographs are prepared for each element of the watershed and routed through the dynamic-storage-indication method to produce various time-based results. Runoff results from 0.25" and 0.5" WQV 24-hour design storms were used to develop appropriately sized treatment systems. These designs were then translated to the SWMM model to determine the larger watershed impacts.

Each of the proposed BMPs 1, 2, 4, 5, 7, 8 and 9, they require the addition of a weir in the existing drainage network in order to re-direct flow to the infiltration system. One major concern is to ensure that sufficient velocity exists for scouring sediment within the pipe network and to avoid added maintenance. A hydraulic analysis was conducted to evaluate pipe flow velocities upstream of BMPs 1, 2, and 5 both with and without the proposed weirs. The analysis showed that sufficient flow velocities will be

[10] Methodology and results are summarized in the memorandum prepared by Geosyntec Consultants, dated 21 October 2016, entitled "Storm Sewer Infrastructure Model Evaluation; 10-yr Design Storm Analysis; Exeter, New Hampshire"

maintained even with the addition of the weirs. The velocities drop near the weir for the water quality design of 0.25-0.5” and for greater storms the velocity remains high and pipe scour will occur insuring no issues with sedimentation. A table showing detailed modeling results for this analysis is provided in Appendix F: Watershed Modeling.

10. BMP Performance and Pollutant Load Reduction

For each location and proposed BMP a pollutant loading analysis was performed in order to quantify the potential to reduce total nitrogen loads from the Lincoln Street watershed. Nitrogen removal performance was based on values derived as part of the WISE (2015) study, using pollutant load export rates (PLERs), BMP types, drainage areas, land uses, and soil types. Results were compiled for the final recommended BMPs (1, 2, 3, 4, 5, 7, 8 and 9) and are presented in Table 4.

The greatest potential nitrogen load reductions are expected from BMPs 1, 2, 4, 5 and 8, due to the fact that the drainage areas for each of these BMPs are quite large. All of the BMPs, with the exception of BMP 5 AND BMP 7, are expected to control at least ¾ of the total nitrogen load from their respective drainage area. The reason that the portion of total load reduction associated with BMP 5 and BMP 7 is much lower than the other systems is because these systems were only sized to manage the ¼" and 0.15" water quality volume, respectively, due to space constraints at the proposed sites.

The total annual nitrogen load from the entire Lincoln Street watershed is 1,265 pounds. Installation of BMPs 1, 2, 3, 4, 5, 7, 8 and 9 is expected to reduce this load by 691 pounds annually, a 76% reduction.

The unit cost performance averaged $1,000 and ranged from $498 - $5,080 per pound of nitrogen. Unit costs for WWTF typically range from $1,000-$3,000 and is estimated to be $1,200 for the new Exeter facility at $3 mg/L and have been estimated at $2,600 for the Durham WWTF facility upgrade.

Table 4: Pollutant Load Reduction and Performance for Priority BMPs 1, 2, 3, and 5 for ½" Water Quality Volume

LOCATION	BMP #	DRAINAGE AREA (ACRES)	ANNUAL TN LOAD (LBS)	ANNUAL TN LOAD REDUCTION (LBS)	% LOAD REDUCTION	$/LBS NITROGEN
WINTER STREET	1	12.88	90.1	68.2	76%	$680
	2*	24.56	157.6	120.2	76%	$660
LINCOLN STREET NORTH	3.1	0.20	2.5	2	80%	$4,000
	3.2	0.13	1.7	1.3	76%	$5,080
	3.3	0.27	3.4	2.6	77%	$4,620
	3.4	0.22	2.9	2.2	77%	$4,500
	3.5	0.24	2.4	1.8	75%	$3,890
	3.6	0.78	7.2	5.7	79%	$3,830
	3.8	1.20	9.1	7.1	78%	$3,100
	3.9	0.70	5.6	4.2	75%	$3,240
	3.22	0.20	1.3	1.0	74%	$3,000
LINCOLN STREET SOUTH	3.20	1.60	13.9	10.7	77%	$3,090
	3.21	0.24	1.4	1.0	72%	$2,800
LINCOLN STREET ELEMENTARY	4	32.43	255.3	230	90%	$1,131
FRONT STREET	5	20.29	138.3	71.7	52%	$640
LINCOLN STREET ELEMENTARY	7	7.41	58.1	7	12%	$4,561
FRONT STREET	8	15.99	108.4	107	99%	$498
TAN LANE	9	5.86	47.6	47	99%	$713
Totals	**-**	**125.2**	**906.9**	**691.2**	**69%**	**$1,000**

11. Flood Reduction and Damage Avoidance

a. BMP Flood Reduction

The existing CAPE SWMM model was updated to include the proposed BMPs 1, 2, 3, 4, 5, 7, 8 and 9 in order to analyze the flood reduction benefits associated with the BMPs both from a standpoint of flood duration (using the SWMM 1-D model) and flooding extent (using the PCSWMM 2-D model) during a 10-year, 24-hour storm event. Results from this analysis are presented in Figure 33, Figure 34, and Figure 35.

Although none of the BMPs are designed to manage a 10-year storm (4.72" of runoff; each BMP is designed to handle 0.5" of runoff with BMP 5 designed to manage 0.25" and BMP 7 designed to manage 0.15"), modeling results indicate that they will have a significant impact on flood duration at 12 major catch basins and manholes, as well as flood extent reductions at many key locations within the Lincoln Street watershed.

Results shown in Table 5 and ***Figure 32*** through Figure 33 indicate for the current conditions there is a 12 million gallon decrease in total runoff and a reduction in runoff depth from 4.11" to 1.65" (60% reduction) during the 10-year, 24-hour storm event following installation of the recommended suite of BMPs. This translates to significant flooding extent reduction benefits along railroad avenue (just downstream of BMPs 1 and 2), along Lincoln Street (just downstream of BMPs 3.1-3.22), and along Front Street (just upstream of BMP 5).

Flood reductions benefits were also examined for a future 10-year storm flood condition for the year 2040 with sea level rise of 9.2' based on the COAST model predictions. For the future condition year 2040 a 13 million gallon decrease in total runoff and a reduction in runoff depth from 5.35" to 2.67" (50% reduction) during the 10-year, 24-hour storm event following BMP installation. This is a significant finding given that the BMPs have only been sized for 0.25-0.5" water quality event, and not flood reduction.

Table 5 – Flood Reductions Results Summary

Year	Storm	Storm Depth	Storm Surge	Scenario	Flow Volume at Outfall	Runoff Depth Equivalent	% Runoff Reduction
2018	10-yr, 24-hr	4.72"	0 ft	Baseline	20 Million Gallons	4.11"	60%
	10-yr, 24-hr	4.72"	0 ft	WQV BMPs	8 Million Gallons	1.65"	
2040	10-yr, 24-hr	5.29"	9.21 ft	Baseline	26 Million Gallons	5.35"	50%
	10-yr, 24-hr	5.29"	9.21 ft	WQV BMPs	13 Million Gallons	2.67"	

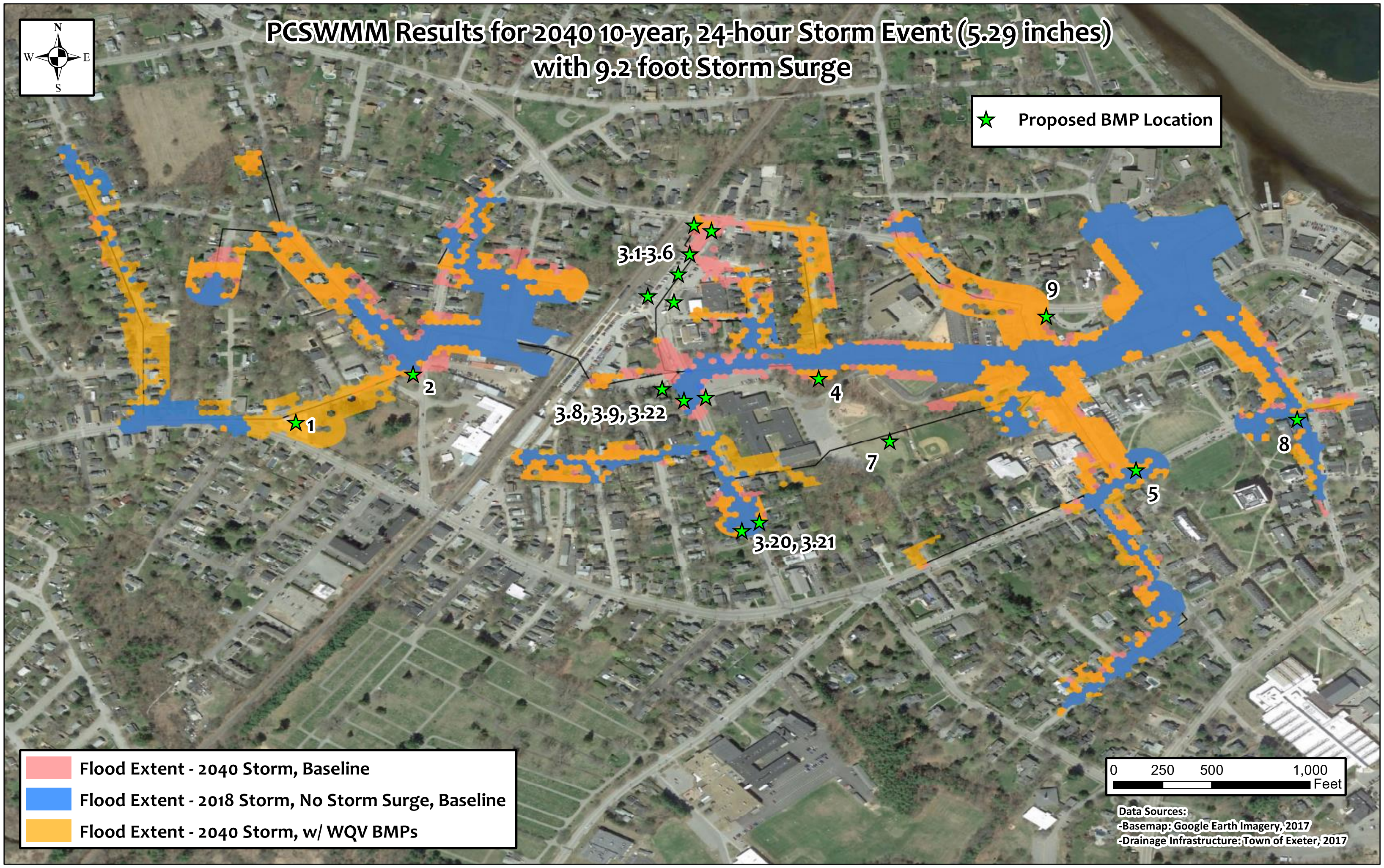


Figure 32: Modeled Flood Reduction Impacts of all BMPs during 2040 10-yr Storm with Storm Surge

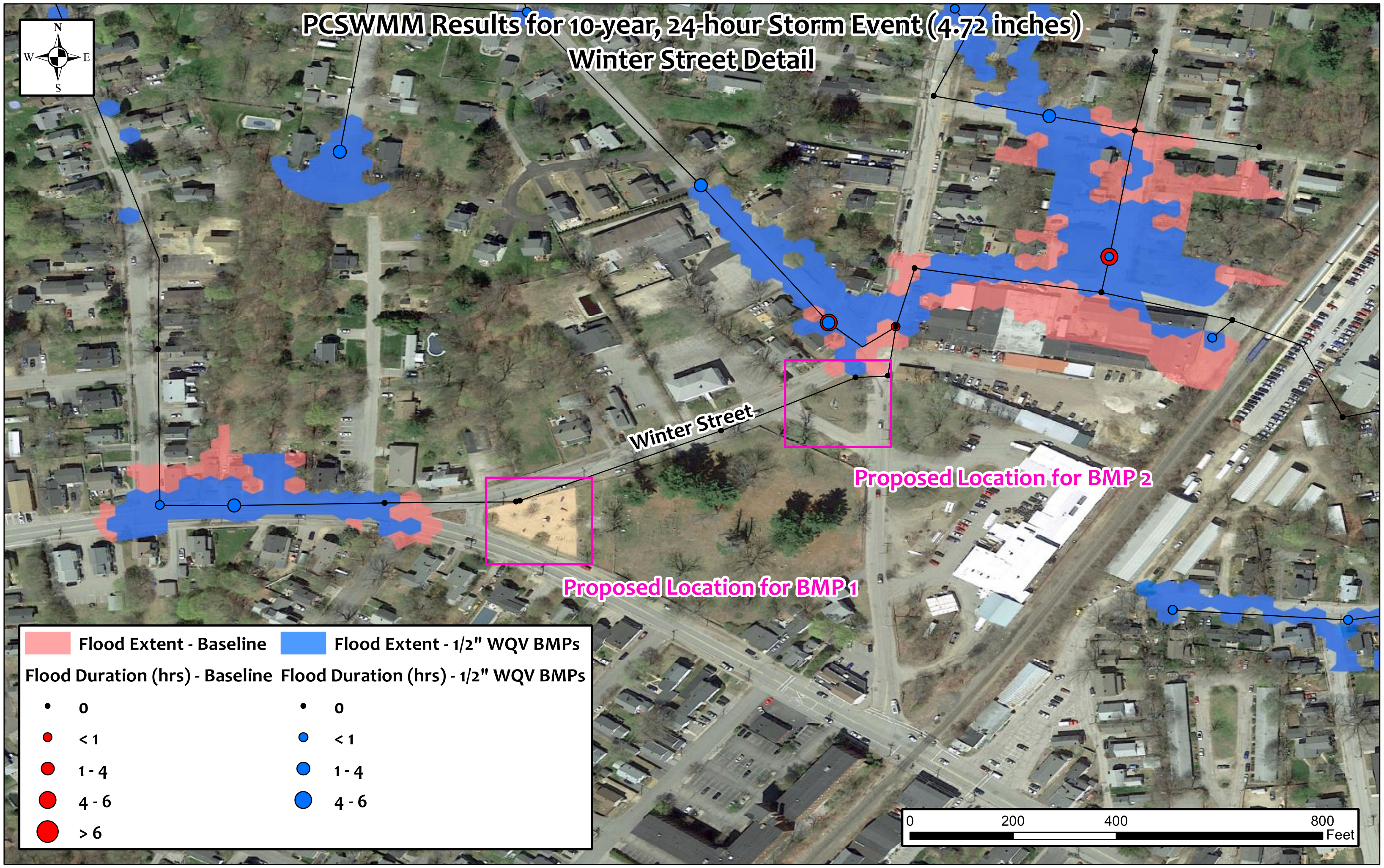


Figure 33: Modeled Flood Reduction Impacts of BMPs 1 and 2 (sized for 1/2" WQV)

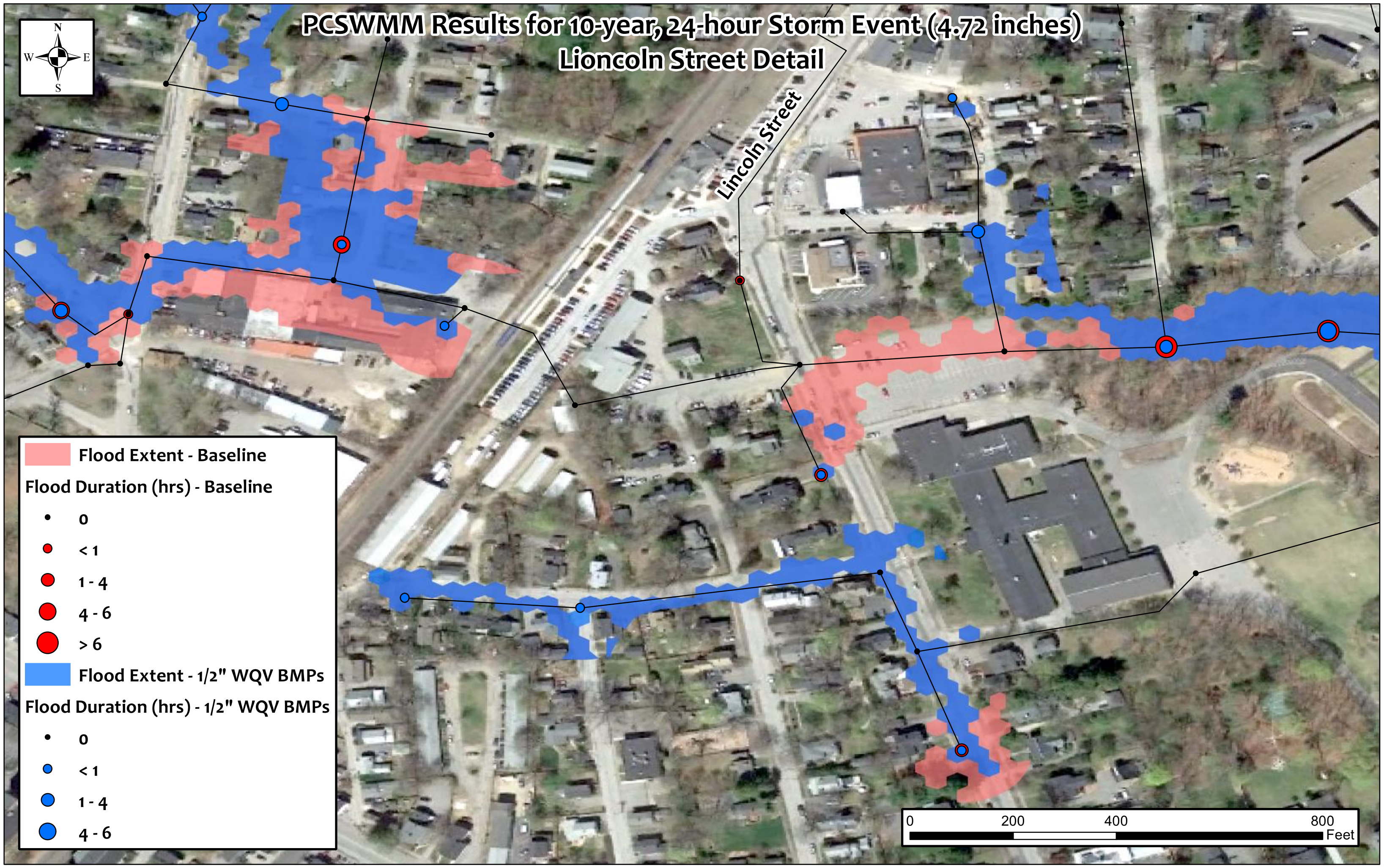


Figure 34: Modeled Flood Reduction Impacts of BMP 3 (sized for 1/2" WQV)

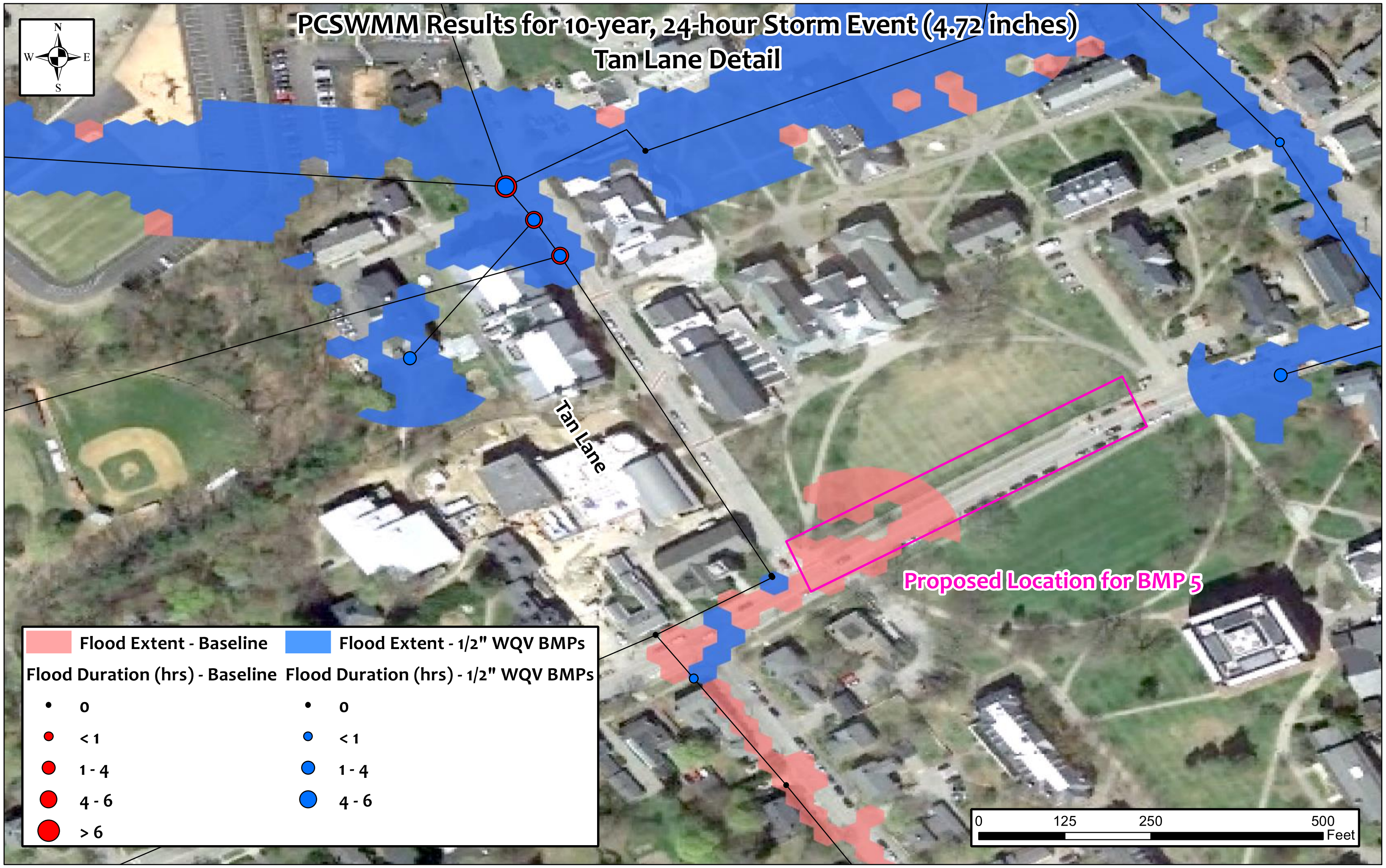


Figure 35: Modeled Flood Reduction Impacts of BMP 5 (sized for 1/4" WQV)

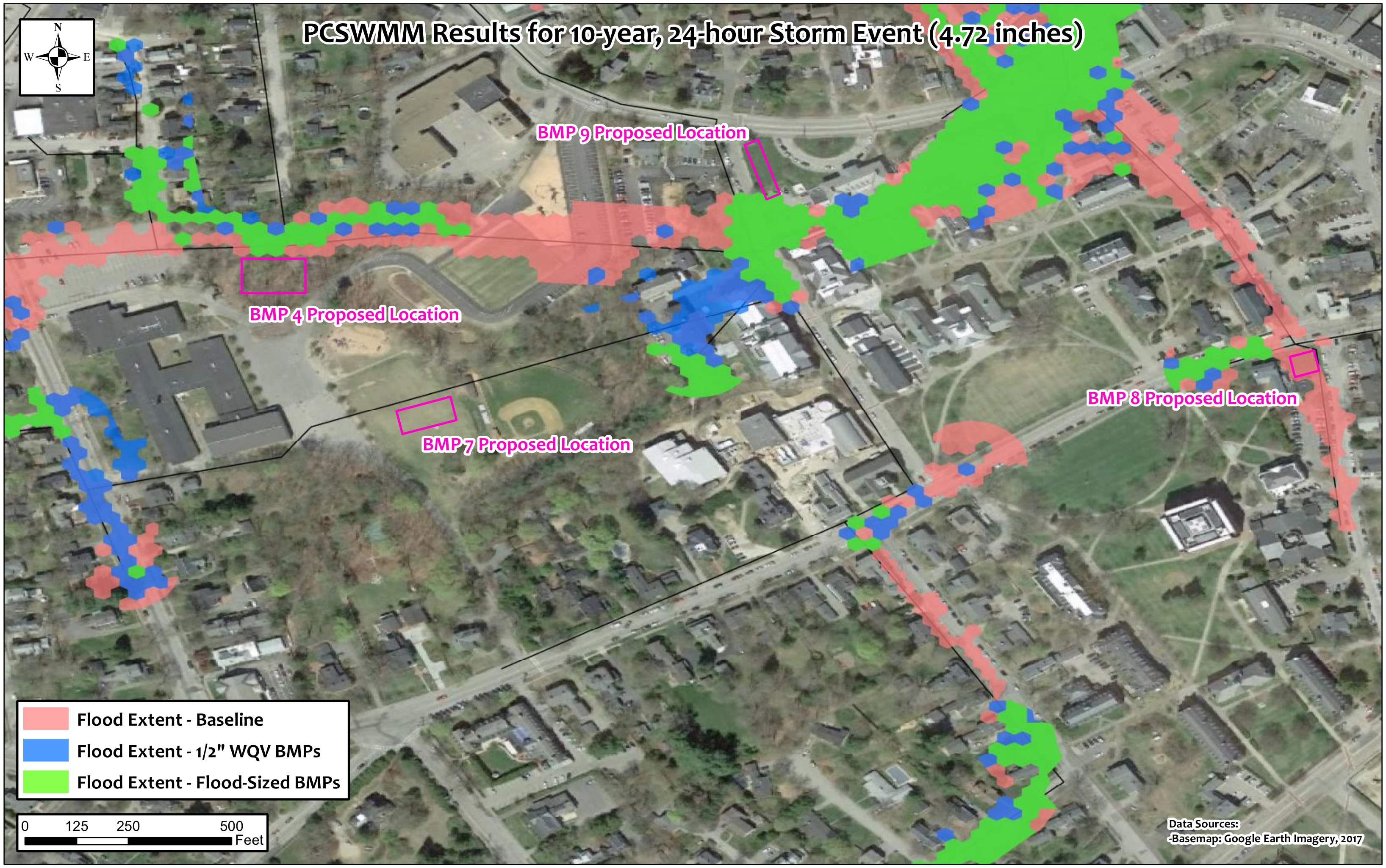


Figure 36: Modeled Flood Reduction Impacts of BMPs 4, 7, 8, and 9 (sized for 1/2" WQV, BMP 7 sized for 0.15" WQV)

b. Flood Damage Avoidance and Economic Impact Analysis

An economic impact analysis was conducted to evaluate cost impact from flooding under current and future conditions and to assess the damage avoidance potential with green infrastructure. This was conducted using HAZUS, a regional multi-hazard loss estimation model, that was developed by the Federal Emergency Management Agency (FEMA) and the National Institute of Building Sciences (NIBS). The primary purpose of HAZUS is to provide a methodology and software application to develop multi -hazard losses at a regional scale. These loss estimates would be used primarily by local, state and regional officials to plan and stimulate efforts to reduce risks from multi-hazards and to prepare for emergency response and recovery.

The economic impact analyses estimated that the total economic loss resulting from flood damage from a current 10-YR flood for baseline conditions was $6.11 million compared to $3.43 million or a 51% reduction under a scenario with implementation of green infrastructure BMPs. Additionally, the analyses estimated that the total economic loss resulting from flood damage under future 2040 conditions for a 10-YR flood with storm surge and no BMPs was $16.5 million compared to $14.62 million under the same conditions but with BMPs included. Of significant note is the evaluation of the flood reduction benefit using small sized BMP of 0.5” water quality volume, which typically are not used for flood reduction. While it is true that small sized BMPs do not prevent flooding, they do provide very significant reductions of more common nuisance flooding in addition to important pollutant load reduction benefits.

Using FEMA’s HAZUS program, the economic impact analysis was evaluated under a variety of scenarios. The geographical size of the region that was evaluated is approximately 20 square miles and contains 396 census blocks. The region contains over 6 thousand households and has a total population of 14,306 people (2010 Census Bureau data). There are also an estimated 5,276 buildings in the region with a total building replacement value (excluding contents) of $1,839 million. Approximately 88.84% of the buildings (and 70.89% f the building value) are associated with residential housing.

The economic impact analysis considered the following scenarios:

- Flood damage for current 10-YR flood without implementation of BMPs (baseline conditions).
- Flood damage for current 10-YR flood with implementation of BMPs.
- Flood damage for 10-YR flood with storm surge for future 2040 conditions without implementation of BMPs.
- Flood damage for 10-YR flood with storm surge for future 2040 conditions with implementation of BMPs.

i. Comparison of Current 10-YR Floods with and without BMPs

Building Damage

HAZUS estimates that about 6 residential buildings will be at least slightly damaged and about 1 residential buildings will be at least moderately damaged in the baseline report (without implementation of BMPs) and that about 5 residential buildings will be at least slightly damaged with the 0.5” WQV BMP retrofits included. The “damage states” are derived from the percent damage (e.g., 1-10% damage is considered slight, 11-50% damage is considered moderate, and 51-100% is considered substantial damage). Table 3 in both reports summarizes the expected damage by general occupancy for the buildings in the region and Table 4 — also in both reports — summarizes the expected damage by general building type.

According to data from Table 3 in both reports, 88% of the damages are characterized as slight and 13% are characterized as moderate under the baseline conditions scenario and 100% of the damages are characterized as slight under the BMP retrofit scenario.

Essential Facility Damage

Under both the baseline scenario and the BMP retrofits scenario no damage to essential facilities is expected.

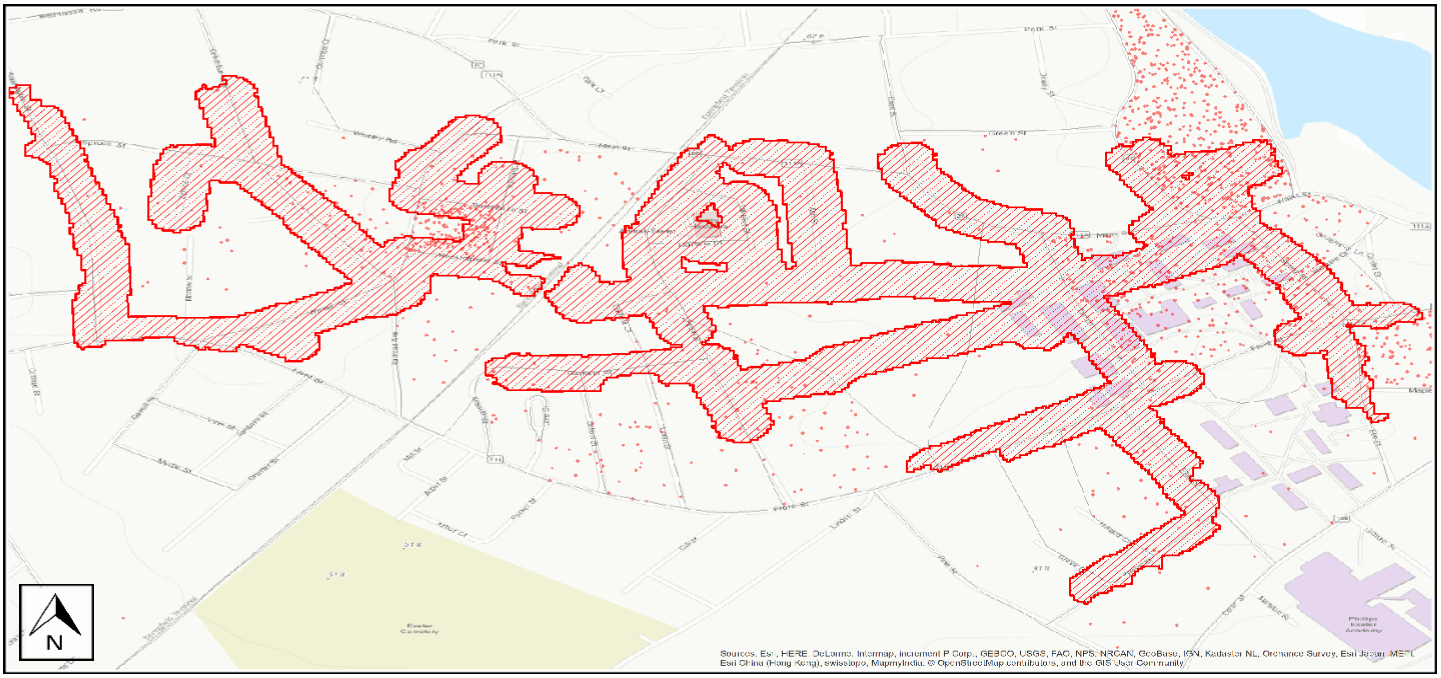


Figure 37: Total Economic Loss (1 dot = $300K) Overview Map

Social Impact

HAZUS estimated the number of households that are expected to be displaced from their homes due to the 10-YR flood and the associated potential evacuation for both scenarios. HAZUS also estimated those displaced people that will require accommodations in temporary public shelters. Under the baseline scenario, the model estimates 51 households (or 153 people) will be displaced due to flooding. Displacement includes households evacuated from within or very near to the inundated area. Under the 0.5" WQV BMPs scenario, the model estimates 35 households (or 106 people) will be displaced due to flooding. Of these displaced people, 2 (out of a total population of 14,306) will seek temporary shelter in public shelters under both scenarios.

Economic Loss

The total economic loss estimated for the 10-YR flood under baseline conditions is $6.11 million, which represents 1.859 % of the total replacement value of the scenario buildings. Under the BMP retrofit scenario, the total economic loss is estimated at $3.43 million, which represents .912 % of the total replacement value of the scenario buildings.

Building-Related Losses

The building losses are broken into two categories: direct building losses and business interruption losses. The direct building losses are the estimated costs to repair or replace the damage caused to the building and its contents. The business interruption losses are the losses associated with inability to operate a business because of the damage sustained during the flood. Business interruption losses also include the temporary living expenses for those people displaced from their homes because of the flood.

The total building-related losses under the baseline conditions scenario were estimated at $1.15 million with the business interruption losses estimated at $4.95 million (accounting for 82% of the estimated losses). By comparison, the total building-related losses under the BMP retrofit scenario were estimated at $0.18 million with the business interruption losses estimated at $3.25 million (accounting for 95% of the estimated losses).

Residential occupancies accounted for 36.01% of the total loss under the baseline conditions scenario and 35.50% of the total loss under the BMP retrofit scenario.

ii. Comparison of 10-YR Floods with Storm Surge with and without BMPs for Future 2040 Conditions

Building Damage

HAZUS estimates that about 17 residential buildings will be at least slightly damaged and about 2 residential buildings will be at least moderately damaged under future 2040 conditions for a 10-YR flood including storm surge with no BMPs and that about 15 residential buildings will be at least slightly damaged and about 3 residential buildings will be at least moderately damaged under future 2040 conditions for a 10-YR flood including storm surge with BMPs.

According to data from Table 3 in the report comprising future 2040 conditions for a 10-YR flood including storm surge with no BMPs, 89% of the damages are characterized as slight and 10% are characterized as moderate. By comparison, data from Table 3 in the report comprising future 2040 conditions for a 10-YR flood including storm surge with BMPs, 83% of the damages are characterized as slight and 17% are characterized as moderate.

Essential Facility Damage

Under the baseline scenario, of the 10 schools in the study area, 2 would receive at least moderate damage with no schools experiencing at least substantial damage or loss of use. Under the WQV BMPs scenario, of the 10 schools in the study area, 1 would receive at least moderate damage with no schools experiencing at least substantial damage or loss of use.

Social Impact

HAZUS estimated the number of households that are expected to be displaced from their homes due to the 10-YR flood including storm surge and the associated potential evacuation for both future 2040 scenarios. HAZUS also estimated those displaced people that will require accommodations in temporary public shelters. Under the baseline scenario, the model estimates 91 households (or 274 people) will be displaced due to flooding. Displacement includes households evacuated from within or very near to the inundated area. Of these displaced people, 4 (out of a total population of 14,306) will seek temporary shelter in public shelters. Under the 0.5" WQV BMPs scenario, the model estimates 81 households (or 244 people) will be displaced due to flooding. Of these displaced people, 2 (out of a total population of 14,306) will seek temporary shelter in public shelters.

Economic Loss

The total economic loss estimated for the 10-YR flood including storm surge under future 2040 conditions with no BMPs is $16.5 million, which represents 4.808 % of the total replacement value of the scenario buildings. Under the BMP retrofit scenario for future 2040 conditions, the total economic loss is estimated at $14.62 million, which represents 4.429 % of the total replacement value of the scenario buildings.

Building-Related Losses

The total building-related losses for the 10-YR flood including storm surge under future 2040 conditions with no BMPs were estimated at $7.39 million with the business interruption losses estimated at $9.11 million (accounting for 55% of the estimated losses). By comparison, the total building-related losses under the BMP retrofit scenario for future 2040 conditions were estimated at $6.71 million with the business interruption losses estimated at $7.92 million (accounting for 56% of the estimated losses).

Residential occupancies accounted for 45.54% of the total loss under the baseline conditions scenario and 46.96% of the total loss under the BMP retrofit scenario.

iii. Comparison of Estimated Damages for a 10-YR 24-Hour Storm: Baseline Flooding Vs. 0.5” BMPs

The figures and Table 6 below summarize the information presented above for both baseline flooding and for flooding with 0.5” BMPs under a 10-YR 24-hour storm and a 2040 10-YR 24-hour storm with a storm surge. As shown, implementation of 0.5” BMPs is estimated to reduce building damages by 86% and decrease business damages by 51%. Similarly a reduction of 47 and 30 displaced persons (31% and 11%) respectively for the current and future 2040 conditions, and a reduction in 50% of essential facilities for the future condition was estimated.

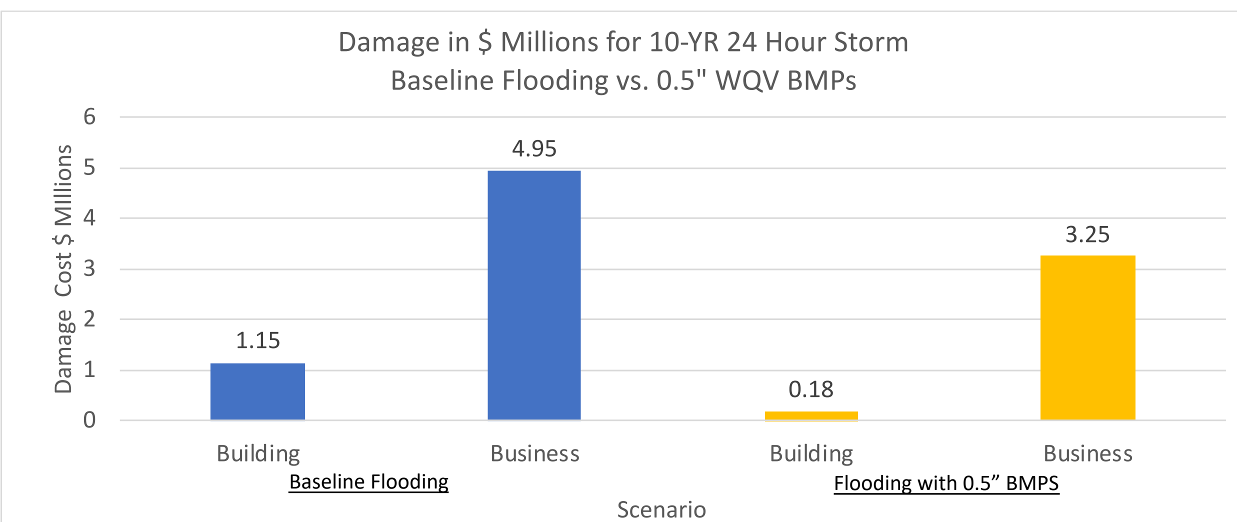


Figure 38: Comparing damages for a 10-YR 24-hour storm under both baseline flooding conditions and 0.5” of BMPs

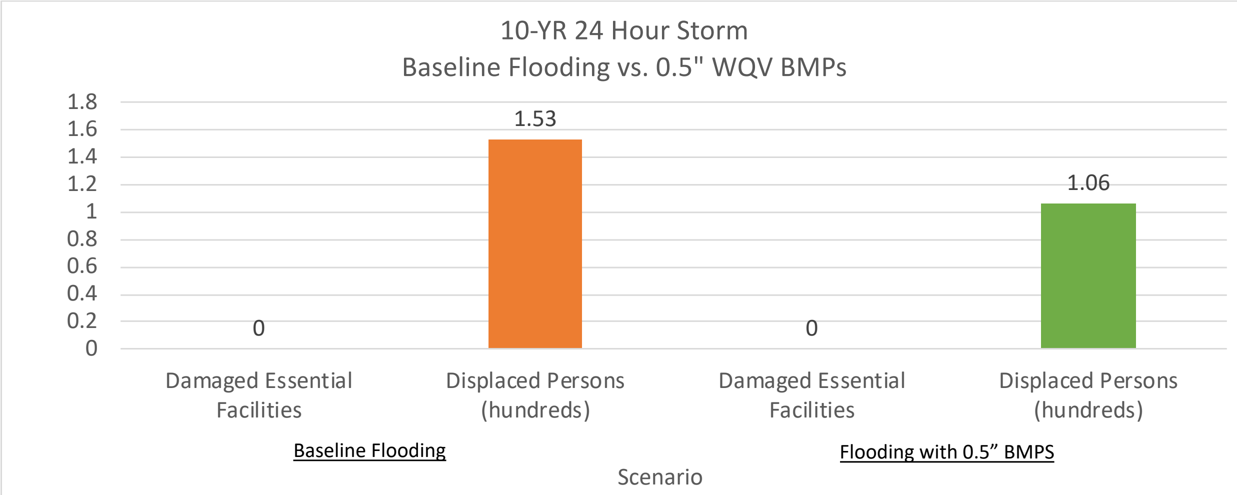


Figure 39: Comparing displaced persons and damaged essential facilities for a 10-YR 24-hour storm with under both baseline flooding conditions and 0.5" of BMPs

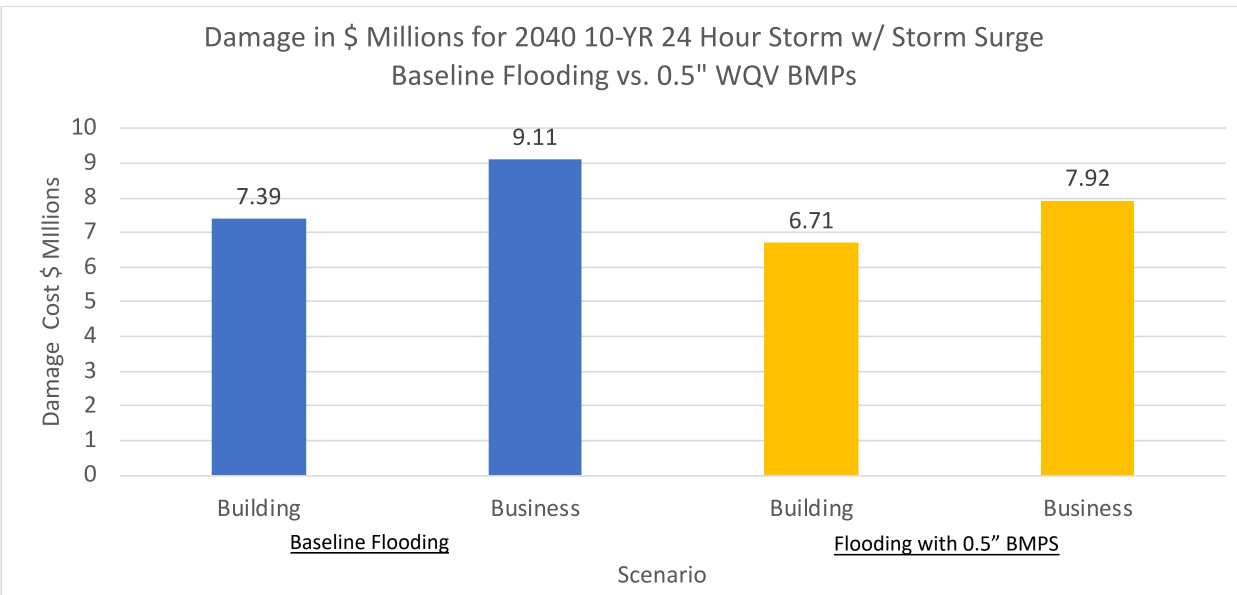


Figure 40: Comparing damages for a 2040 10-YR 24-hour storm with a storm surge under both baseline flooding conditions and 0.5" of BMPs

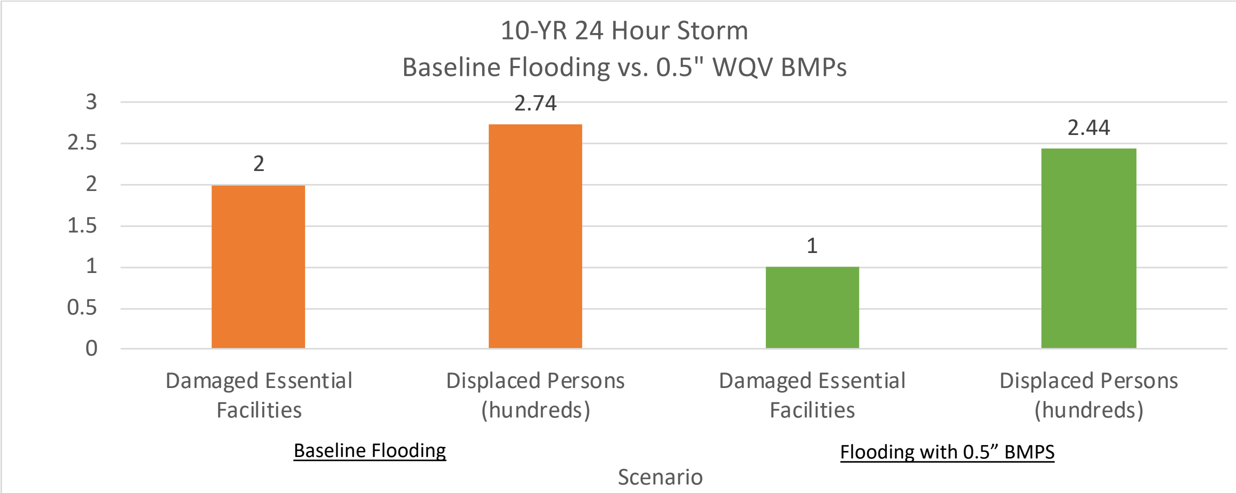


Figure 41: Comparing displaced persons and damaged essential facilities for a 10-YR 24-hour storm with a storm surge with under both baseline flooding conditions and 0.5" of BMPs

HAZUS Scenario	Building Damage	Essential Facilities Damage	Social Impact	Total Economic Loss	Direct building losses	Business interruption losses
Baseline	6 residential buildings at least slightly damaged; 1 residential building at least moderately damaged	none	51 households (or 153 displaced); 2 people will seek temporary shelter in public shelters	$6.11 million	$1.15 million	$4.95 million
WQV BMPs	5 residential buildings at least slightly damaged	none	35 households (or 106 displaced); 1 person will seek temporary shelter in public shelters	$3.43 million	$0.18 million	$3.25 million
2040 SLR no BMPs	17 residential buildings at least slightly damaged; 2 residential buildings at least moderately damaged	none	91 households (or 274 displaced); 4 people will seek temporary shelter in public shelters	$16.5 million	$7.39 million	$9.11 million
2040 SLR with BMPs	15 residential buildings at least slightly damaged; 3 residential buildings at least moderately damaged	none	81 households (or 244 displaced); 2 people will seek temporary shelter in public shelters	$14.62 million	$6.71 million	$7.92 million

Table 6: Economic Impact Analyses for Current and Future 2040 Flood Conditions with and without Green Infrastructure BMPs

12. ENGINEERING COST ESTIMATES

A costing analysis was performed to quantify the total and unit costs (cost per pound of nitrogen removed) for each BMP. Engineering cost estimates were developed based on materials quantities, labor, and equipment for BMPs 1, 2, 3, 4, 5, 7, 8 and 9 and are shown in Table 7. A more detailed look at the costing analysis is provided in Appendix I: Engineering Cost Estimates.

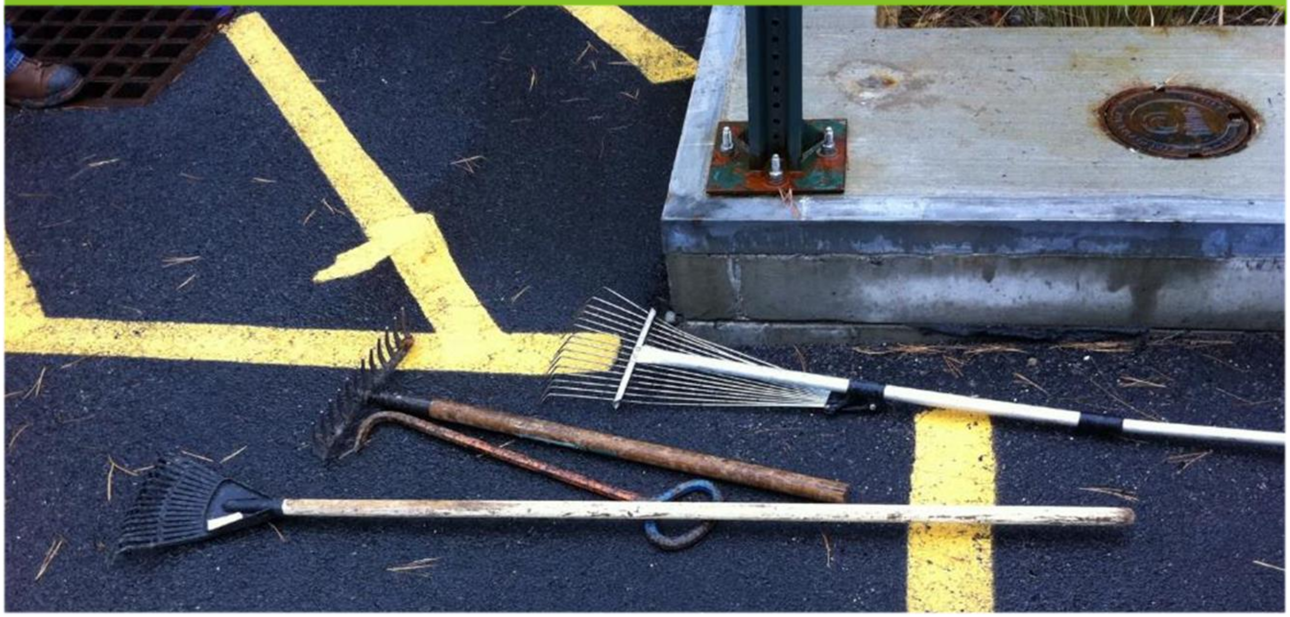
Of particular note is the low unit costs ($ per pound of nitrogen loading reduction) associated with the subsurface infiltration systems (BMPs 1, 2, 4, 5, 8 and 9). For all of these systems (with the exception of BMP 4, which requires a significant cut and fill operation), the unit cost is estimated at well below $1,000, representing an extremely economical option for reducing nitrogen loading in the Lincoln Street watershed. BMPs 1, 2, 4, 5 and 8 all manage runoff from large drainage areas, making it possible to achieve economies of scale not possible for BMPs 3.1-3.22. These ROW infiltration and tree planter systems have relatively small drainage areas (< 2 acres) meaning they will each handle fairly small nitrogen loads. Nevertheless, $3,000-$5,000 (the unit cost per pound of nitrogen loading reduction associated with BMPs 3.1-3.22) is still a worthwhile expenditure, especially given that each of these systems is expected to control around ¾ of the total nitrogen load from their respective drainage areas.

Tremendous cost saving opportunities exist when BMP retrofits are timed with road and utility improvements. For example, a bioretention system designed to treat 1 acre of runoff might cost an estimated $40,000. However, when paired with road improvements the costs may be reduced to $10,000 due to the shared costs of curbs, sidewalks, and roads.

Table 7: Engineering Cost Estimates for BMPs 1, 2, 3, 4, 5, 7, 8 and 9

LOCATION	BMP #	DRAINAGE AREA (ACRES)	ANNUAL TN REDUCTION (LBS)	% LOAD REDUCTION	95% DESIGN COST ESTIMATE	$/LBS NITROGEN
WINTER STREET	1	12.9	68.2	76%	$45,900	$680
	2	24.6	120.2	76%	$79,000	$660
Subtotal	-	**37.4**	**188.4**	**76%**	**$124,900**	-
LINCOLN STREET NORTH	3.1	0.2	2.0	80%	$8,000	$4,000
	3.2	0.1	1.3	76%	$6,600	$5,080
	3.3	0.3	2.6	77%	$12,000	$4,620
	3.4	0.2	2.2	77%	$9,900	$4,500
	3.5	0.2	1.8	75%	$7,000	$3,890
	3.6	0.8	5.7	79%	$21,800	$3,830
	3.8	1.2	7.1	78%	$22,000	$3,100
	3.9	0.7	4.2	75%	$13,600	$3,240
	3.22	0.2	1.0	77%	$3,000	$3,000
Subtotal	-	**3.9**	**27.9**	**77%**	**$103,900**	-
LINCOLN STREET SOUTH	3.20	1.6	10.7	77%	$33,000	$3,090
	3.21	0.2	1.0	72%	$2,800	$2,800
Subtotal	-	**1.8**	**11.7**	**76%**	**$35,800**	-
FRONT STREET	5	20.3	71.7	52%	$45,200	$640
PHASE 2	4	32.43	230	90%	$259,900	$1,130
	7	7.41	7	12%	$33,100	$4,560
	8	15.99	107	99%	$53,500	$500
	9	5.86	47	99%	$33,600	$700
Subtotal	-	**61.7**	**391**	**83%**	**$380,000**	**$970**
Total	-	**125**	**691**	**76%**	**$689,825**	-

13. MAINTENANCE CONSIDERATIONS



A detailed Operations and Maintenance Plan has been developed for the proposed BMPs and is provided in Appendix J: Operations and Maintenance Plan. This includes methods, checklists, and annual reporting forms. All BMPs will incorporate low maintenance design elements with an emphasis on pre-treatment to reduce maintenance needs. A series of maintenance fact sheets and recommendations are also provided in Appendix J: Operations and Maintenance Plan for tree planters, right-of-way infiltration, and subsurface infiltration. The focus on pre-treatment will provide easy-to-maintain shallow sumps for collection of sediment and trash with standard maintenance procedures using vactor trucks and requires no specialty equipment or training. The location of curb cuts will be spaced to optimize the function of existing drainage infrastructure. Low maintenance asset management with pretreatment has the following goals:

- In urban environments return on investment may be 1-2 years
- Use existing staff, equipment for standard catch basin cleaning
- Management of urban land-use with high trash and debris load
- Improved aesthetics
- Cost to maintain versus cost of pretreatment

To ensure the effectiveness of BMPs, regular inspections and maintenance is necessary. Generally speaking, inspection and maintenance falls into two categories: expected routine maintenance and non-routine (repair) maintenance. Routine maintenance is performed regularly to maintain both aesthetics and good working order of BMPs. Routine inspection and maintenance helps prevent potential nuisances (odors, mosquitoes, weeds, etc.), reduces the need for repair maintenance, and insures long term performance.

Under MS4 rules, owners and operators are responsible for implementing BMP inspection and maintenance programs and having penalties in place to deter infractions. The rules recommend that all stormwater BMPs should be inspected on a regular basis for continued effectiveness and structural integrity.

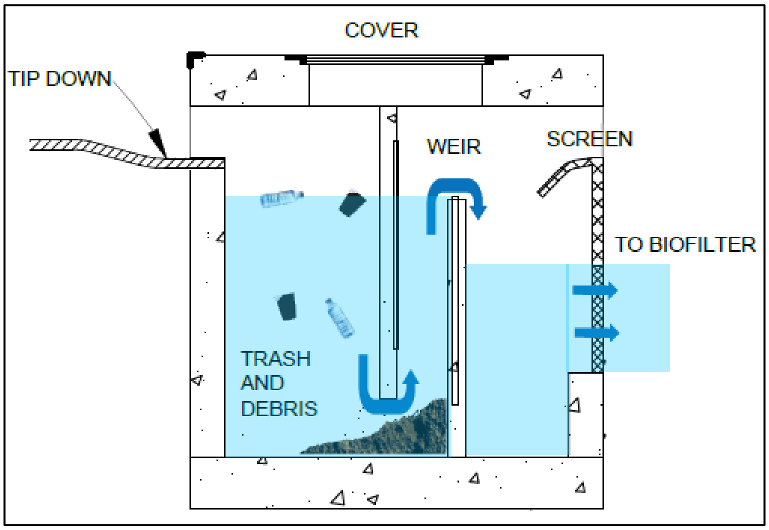
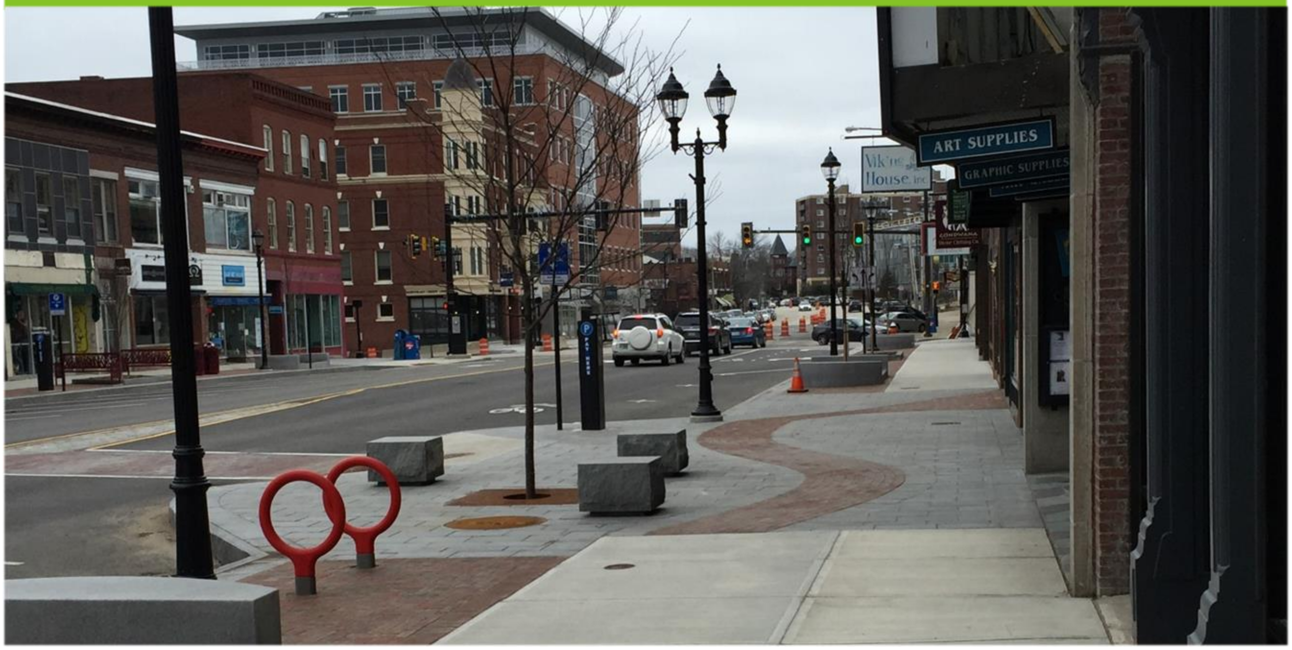


Figure 42: Pretreatment example minimizing and focusing maintenance in catchbasin

14. Recommendations



As part of a future Phase III effort, we recommend pursuing further analyses to study additional subwatersheds. Suitable soils appear to be present throughout the town of Exeter. BMPs installed in these locations would likely have substantial flood reduction and water quality benefits given that they represent most of the major trunklines (including Phase I) within the S10 and other Exeter watersheds.

Furthermore, implementation of the recommendations will help Exeter address requirements of EPA's 2017 NH Small MS4 General Permit for stormwater discharges. In particular new requirements to develop a Nitrogen Source Identification Report; and new development and redevelopment stormwater management BMPs be optimized for nitrogen removal; retrofit inventory and priority ranking to reduce nitrogen discharges.

15. REFERENCES

1. Arcieri, W., Henderson, Z., and Cedarholm, D. (2014). "Oyster River Integrated Watershed Management Plan." Vanasse Hangen Brustlin, Woodard and Curran, Town of Durham, Durham, NH.
2. Audubon Society of New Hampshire, UNH Cooperative Extension, NRCS, and NH Office of State Planning (1997). "Buffers for Wetlands and Surface waters. A Guidebook for New Hampshire Municipalities."
3. Bierman, V. J., Diaz, R. J., Kenworthy, W. J., and Reckhow, K. H. (2014). "Joint Report of Peer Review Panel-Great Bay Estuary."
4. Breaults, R.F., Sorenson, J.R., and Weiskel, P.K. (2002). "Streamflow, Water Quality, and Contaminant Loads in the Lower Charles River Watershed, Massachusetts, 1999–2000." USGS Water Resources Investigations Report 02-4137, U.S. Department of Interior.
5. CRWA. (2014). Charles River Watershed Association http://www.crwa.org/project-resources.
6. Chesapeake Stormwater Network. (1997). http://chesapeakestormwater.net/bay-stormwater/baywide-stormwater-policy/urban-stormwater-workgroup/urban-street-sweeping/. Accessed on March 23, 2015.
7. Clar, M., (2003). "Case Study: Pembrook Woods LID Development Residential Subdivision." Ecosite, Inc.
8. CWP, and VA Department of Conservation. (2001). "The Economic Benefits of Protecting Virginia's Streams, Lakes and Wetlands and the Economic Benefits of Better Site Design in Virginia."
9. Elmer, H. (2007). "National Training Priority and Funding Needs Survey." National Estuarine Research and Reserve System (NERRS) Coastal Training Program External Funding Workgroup, Washington, DC.
10. EPA. (1996). EPA Watershed Approach Framework. U.S. Environmental Protection Agency, Washington, DC. http://water.epa.gov/type/watersheds/framework.cfm
11. EPA. (1999). Urban Stormwater Best Management Practices Study, Part D.
12. EPA. (1997). Monitoring Consortiums: A Cost-Effective Means to Enhancing Watershed Data Collection and Analysis (EPA 841-R-97-006). U.S. Environmental Protection Agency, Washington, DC. http://www.epa.gov/owow/watershed/wacademy/its03/mon_cons.pdf
13. EPA. (2004). Water quality trading assessment handbook. Can water quality trading advance your watershed's goals? EPA 841-B-04-001. EPA, Office of Water, Washington, DC. 120 p.
14. EPA. (2007). Watershed-based National Pollutant Discharge Elimination System (NPDES) Permitting Technical Guidance. (EPA 833-B-07-004). U.S. Environmental Protection Agency, Washington, DC. http://www.epa.gov/npdes/pubs/watershed_techguidance.pdf

15. EPA. (2008.) EPA water quality trading evaluation. Final report. EPA Office of Policy, Economics and Innovation. Industrial Economics Contract EP-W-04-023. US EPA, Washington, DC. 90 p.
16. EPA. (2009). Water quality trading toolkit for permit writers. EPA, Washington, DC. 55 p.
17. EPA SAB. (2011). Reactive nitrogen in the United States: An analysis of inputs, flows, consequences, and management options – A report of the EPA Science Advisory Board. Report EPA-SAB-11-013. EPA Science Advisory Board, Integrated Nitrogen Committee. Washington, DC. 172 p.
18. EPA. (2011). Memorandum entitled "Achieving Water Quality through Integrated Municipal Stormwater and Wastewater Plans." Stoner, N., and Giles, C., October 2011, US EPA.
19. EPA. (2012). "Integrated Municipal Stormwater and Wastewater Planning Approach Framework", Stoner, N. and Giles, C., June 2012, USEPA.
20. EPA. (2012). "Authorization to Discharge Under the National Pollutant Discharge Elimination System, The Town of Exeter, New Hampshire, Squamscott River." NPDES Permit No. NH0100871, Office of Ecosystem Protection, U.S. Environmental Protection Agency, Region I, Boston, Massachusetts.
21. EPA. (2013). "2013 NH Small MS4 Draft General Permit, General Permits for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems."
22. EPA. (2014). "Estimating Change in Impervious Area (IA) and Directly Connected Impervious Area (DCIA) for New Hampshire Small MS4 Permit." Small MS4 Permit Technical Support Document, Revised April 2014 (Original Document, April 2011).
23. EPA. (2014). "Financial Capability Assessment Framework for Municipal Clean Water Act Requirements".
24. EPA (2015). Water: Best Management Practices. Landscaping and Lawn Care - Minimum Measure: Public Education and Outreach on Stormwater Impacts http://water.epa.gov/polwaste/npdes/swbmp/Landscaping-and-Lawn-Care.cfm. Accessed March 2015.
25. EPRI. (2013). Case studies of water quality trading being used for compliance with National Pollutant Discharge Elimination System permit limits. Electric Power Research Institute Technical Report 3002001454. EPRI, Palo Alto, CA. 80 p.
26. FB Environmental Associates, Inc. (2009) Long Creek Watershed Management Plan, July 2009, Appendix 7.
27. GBMC. (2010). Adaptive Management Plan. The Great Bay Municipal Coalition, Dover, Exeter, Newmarket, Portsmouth, and Rochester NH.
28. Geosyntec Consultants. (2014). Least Cost Mix of BMPs Analysis, Evaluation of Stormwater Standards Contract No. EP-C-08-002, Task Order 2010-12. Prepared for Jesse W. Pritts, Task Order Manager, U.S. Environmental Protection Agency.
29. Hayes, L., and Horn, M. A. (2009). "Methods for Estimating Withdrawal and Return Flow by Census Block for 2005 and 2020 for New Hampshire." Open-File Report 2009-1168, U.S. Geological Survey, Pembroke, NH.
30. Herrera Environmental. (2011). TAPE Literature Review for Manufactured Treatment Devices, Seattle, Wa.
31. Kim, H., Seagren, E.A., and Davis, A.P. (2003). "Engineering Bioretention for Removal of Nitrate from Stormwater Runoff." Water Environment Research. 75, 355 (2003).
32. Kleinfelder. (2012). "Exeter/Stratham Intermunicipal Water and Wasterwater Systems Evaluation Study and Final Report." Rockingham Planning Commission. December 2012.
33. MADEP. (2008). "Final Total Maximum Daily Load for Nutrients in the Lower Charles River Basin, Massachusetts." Massachusetts Department of Environmental Protection.
34. Narayanan, Arvind and Pitt, Robert. 2006. Costs of Urban Stormwater Control Practices (Preliminary Report).
35. NERRS. (2006). Research and Monitoring Plan (2006-2011).Washington, DC. http://www.NERRS.noaa.gov/pdf/Research_Monitoring.pdf Accessed August, 2008.
36. NHDES. (2008). "New Hampshire Stormwater Manual." New Hampshire Department of Environmental Services. December 2008.
37. NHDES. (2009). "Draft Numeric Nutrient Criteria for the Great Bay". New Hampshire Department of Environmental Services.
38. NHDES. (2010). "Analysis of Nitrogen Loading Reductions for Wastewater Treatment Facilities and Nonpoint Sources in the Great Bay Estuary Watershed". Great Bay Nitrogen Loading Analysis Draft R-WD-10-22.
39. NHDES (2011) The Lower Exeter and Squamscott Rivers A Report to the General Court Prepared by State of New Hampshire Department of Environmental Services Water Division – Watershed Management Bureau
40. NHDES, Trowbridge, P., Wood, M. A., Underhill, J. T., and Healy, D. S. (2014). "Great Bay Nitrogen Nonpoint Source Study." *R-WD-13-10*, NH Department of Environmental Services, Concord, NH.
41. NJDEP. (2014). "New Jersey Stormwater Best Management Practices Manual." New Jersey Department of Environmental Protection. Updated September 2014.

42. NH Sea Grant Fact Sheet ‘Green Grass – Clear Water’ https://seagrant.unh.edu/sites/seagrant.unh.edu/files/media/pdfs/extension/lawncare_information_sheet.pdf
43. PREP. (2010). Comprehensive Conservation and Management Plan. Piscataqua Regional Estuaries Program, Durham, NH.
44. PREP. (2012). "2012 State of Our Estuaries." Piscataqua Region Estuaries Partnership, Durham, NH.
45. PREP. (2015). Piscataqua Region Environmental Planning Assessment (PREPA), Durham, NH.
46. PREP (2018). 2018 State of Our Estuaries. Durham, NH, Piscataqua Region Estuaries Partnership.
47. Roseen, R., Watts, A., Bourdeau, R., Stacey, P., Sinnott, C., Walker, T., Thompson, D., Roberts, E., and
48. Miller, S. (2015). Water Integration for Squamscott Exeter (WISE), Preliminary Integrated Plan, Final Technical Report. Portsmouth, NH, Geosyntec Consultants, University of New Hampshire, Rockingham Planning Commission, Great Bay National Estuarine Research Reserve, Consensus Building Institute.
49. Smith, B. (2014). "Manure Calculator." NRCS, Durham, NH.
50. Stacey, P.E. In Press. Connecticut’s Long Island Sound Nitrogen Credit Exchange. Chapter 12 in Advances in water quality trading as a flexible compliance tool. A Special Publication of the Water Environment Federation. WEF, Alexandria, VA.
51. Stephenson, K. and L. Shabman. 2011. Rhetoric and reality of water quality trading an the potential for market-like reform. J. Amer. Water Works Assn. 47(1):15-28.
52. Stephenson, K., S. Aultman, T. Metcalfe, and A. Miller. 2010. An evaluation of nutrient nonpoint offset trading in Virginia: A role for agricultural nonpoint sources? Water Resources Res. 46:W04519-W04519.
53. Stratus. (2009). "A Triple Bottom Line Assessment of Traditional and Green Infrastructure Options for Controlling CSO Events in Philadelphia's Watersheds." City of Philadelphia Water Department, Boulder, Colorado.
54. SWA. (2012). Southeast Watershed Alliance. http://www.southeastwatershedalliance.org/mission.html
55. SWA, UNHSC, and RPC. (2012). “Model Stormwater Standards for Coastal Watershed Communities.” December 2012.
56. Tetra Tech. (2009). Optimal Stormwater Management Plan Alternatives: A Demonstration Project in Three Upper Charles River Communities, Final Report. Prepared for United States Environmental Protection Agency and Massachusetts Department of Environmental Protection.Underwood Engineers. (2014). “Towns of Exeter and Stratham, NH Regional Wastewater Disposal Options.” November 21, 2014.
57. United States Department of Agriculture (USDA). (2013).
58. UNH Cooperative Extension. 2014. New Hampshire’s Turf Fertilizer Law ‘What You Should Know’. UNH Cooperative Extension Fact Sheet. http://extension.unh.edu/resources/files/Resource004116_Rep5835.pdf
59. UNHSC. (2007). “2007 Biennial Report.” University of New Hampshire Stormwater Center.
60. UNHSC. (2009). “UNHSC Subsurface Gravel Wetland Design Specifications.” June 2009.
61. UNHSC. (2012). “2012 Biennial Report.” University of New Hampshire Stormwater Center.
62. USGS. (2002)."Measured and Simulated Runoff to the Lower Charles River, Massachusetts, October 1999–September 2000."
63. USGS. (2002). "Streamflow, Water Quality, and Contaminant Loads in the Lower Charles River Watershed, Massachusetts, 1999–2000."
64. Valiela, I., Geist, M., McClelland, J., and Tomasky, G. (2000). "Nitrogen loading from watersheds to estuaries: verification of the Waquoit Bay nitrogen loading model." *Biogeochemistry*, 49(3), 277-293.
65. Willamette Partnership, The Freshwater Trust. 2014. Regional recommendations for the Pacific Northwest on water quality trading. USDA Conservation Innovation Grant Award to the Willamette Partnership, November 2012, for Multi-State Agency Guidance for Water Quality Trading: Joint Regional Water Quality Trading Agreement (69-3A75-12-255). Willamette Partnership, Portland, OR. 168 p.
66. Wright-Pierce. (2011). “Wasterwater Management Concept Plan for the Town of Stratham, NH.”
67. Wright-Pierce. (2014). “Town of Exeter, NH, Wastewater Facilities Plan, Preliminary Draft.” October 2014.
68. Zankel, M., C. Copeland, P. Ingraham, J. Robinson, C. Sinnott, D. Sundquist, T. Walker, and J. Alford. 2006. The Land Conservation Plan for New Hampshire’s Coastal Watersheds. The Nature Conservancy, Society for the Protection of New Hampshire Forests, Rockingham Planning Commission, and Strafford Region Planning Commission. Prepared for the New Hampshire Coastal Program and the New Hampshire Estuaries Project, Concord, NH.
69. Zarriello, P.J. and Barlow, L.K. (2002). "Measured and Simulated Runoff to the Lower Charles River, Massachusetts, October 1999–September 2000." USGS Water Resources Investigations Report 02-4129, U.S. Department of Interior.

16. APPENDICES

Appendix A: Factsheets

1. Project Overview
2. Climate Adaptation Policy
3. Stormwater Retrofit Opportunities
4. Economic Benefits of Flood Avoidance
5. Flood Reduction from Green Infrastructure

Appendix B: Outreach Efforts

1. Community Survey on Climate Resiliency
2. Presentation from Southeast Watersheds Alliance
3. Water Trail Signs

Appendix C: Climate Adaptation Plan

Appendix D: Drainage Infrastructure Inventory and Land Use

Appendix E: Soil Test Pit Records

Appendix F: Watershed Modeling and Assumptions and Limitations

1. Modeling Methodology
2. Assumptions And Limitations
3. PCSWMM Output Reports
4. Flood Damage For Current 10-Yr Flood Without Implementation Of BMPS (Baseline Conditions)
5. Flood Damage For Current 10-Yr Flood With Implementation Of BMPS
6. Flood Damage For 10-Yr Flood With Storm Surge For Future 2040 Conditions Without Implementation Of BMPS
7. Flood Damage For 10-Yr Flood With Storm Surge For Future 2040 Conditions With Implementation Of BMPS

Appendix G: HAZUSs Modeling

Appendix H: Pollutant Load Methodology

Appendix I: Engineering Cost Estimates

Appendix J: Operations and Maintenance Plan

Appendix K: 95% BMP Design Package