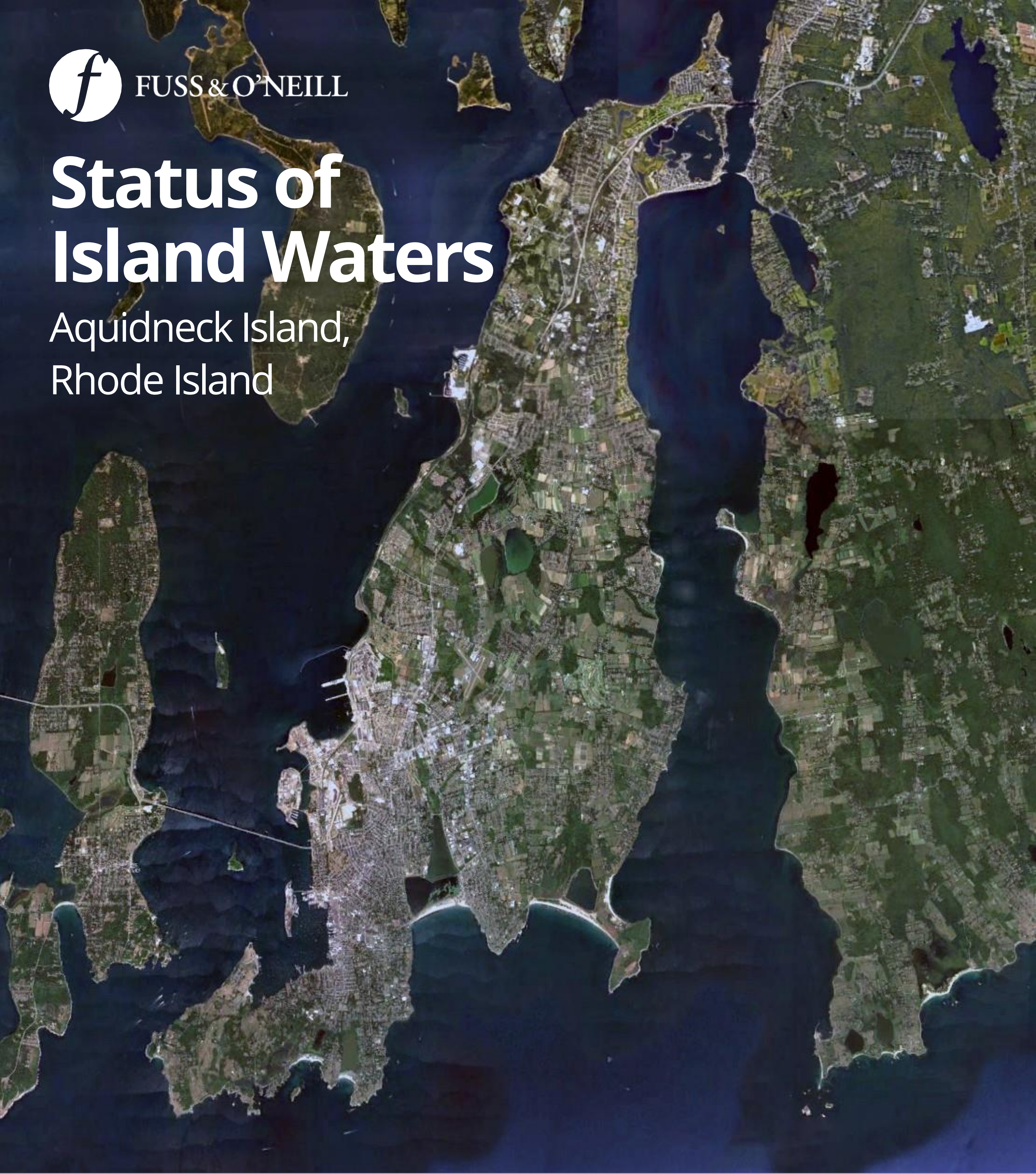

FUSS & O'NEILL

Status of Island Waters

Aquidneck Island, Rhode Island

Aquidneck Island Planning Commission

May 2018

This project has been funded wholly or in part by the United States Environmental Protection Agency under assistance agreement SE00A0136 to Aquidneck Island Planning Commission. The contents of this document to not necessarily reflect the views and policies of the Environmental Protection Agency, nor does EPA endorse trade names or recommend the use of commercial products mentioned in this document.

1 What is the Island Waters Project?

Aquidneck Island's fresh and saltwater resources are immensely valuable – for drinking water, recreation, our communities' quality of life and as the foundation of our coastal economy. Yet the Island's geography, geology and land use make these waters vulnerable to pollution from stormwater runoff.

The Island's lands and waters are shared by three communities: Newport, Middletown, and Portsmouth, Rhode Island, as well as Naval Station Newport. Water flows freely across municipal boundaries, and all three communities contribute to stormwater runoff, while all three experience the impacts of pollution to fresh and salt waters: beach closures, shellfishing bans, and threats to the Island's drinking water supply. Aquidneck Island is the only East Coast island that relies almost entirely on surface reservoirs for its drinking water, and all three communities are home to high-quality public saltwater swimming beaches.

Island Waters is a new program to help the communities of Aquidneck Island restore clean water by working together to effectively manage stormwater pollution. The program was developed by the Aquidneck Island Planning Commission (AIPC) in partnership with Newport, Middletown, Portsmouth, and the non-profit organizations Clean Ocean Access (COA) and the Aquidneck Land Trust (ALT). Other participating partners include the Eastern Rhode Island Conservation District (ERICD), the Rhode Island Departments of Environmental Management, Transportation, and Health (RIDEM, RIDOT and RIDOH, respectively), and the Rhode Island Green Infrastructure Coalition. In September 2016, the U.S. Environmental Protection Agency (EPA) selected **Island Waters** for funding with a three-year grant under its Southeast New England Program (SNEP).

This report is part of the first phase of the **Island Waters** project and provides a summary of the status of waters on and around Aquidneck waters, including current water quality. The report also provides an update on municipal efforts to manage stormwater through municipal separate storm sewer systems (MS4s), and a synthesis of prior studies and existing plans for potential stormwater best management practices (BMPs). Taken together, the elements of this report are intended to provide the communities and stakeholders of Aquidneck Island with a better understanding of stormwater impacts on the Island's water resources, while pointing toward effective solutions that can be implemented by the **Island Waters** program, as well as independently by the communities and other stakeholders.

What We Will Accomplish

The goal of **Island Waters** is to assist the communities and stakeholders of Aquidneck Island in restoring fresh and salt waters by reducing polluted stormwater runoff to the Island's reservoir system, other fresh water bodies, and local coastal waters. We're focusing initially on some of the principal threats to the Island's drinking water and swimming beaches – nutrients (fertilizers such as nitrogen and phosphorus) and bacteria.

Island Waters is producing real and immediate improvements to restore clean water on Aquidneck Island, while establishing a framework for better stormwater management in the future. Together, the **Island Waters** partners are:

- Investing roughly $1 million in stormwater improvements Island-wide;
- Protecting Aquidneck Island's drinking water system;
- Reducing direct pollution sources to coastal waters;
- Engaging and informing Island residents about watershed stewardship;
- Assisting Island municipalities in identifying funding sources for clean water; and
- Sharing results with other communities in New England and beyond.

Ultimately, it is the intention of **Island Waters** to serve as a basis for increasingly integrated water resources and habitat planning, policy, and implementation, including the development of sustainable funding mechanisms for water quality management. Working together, the communities of Aquidneck Island can reduce stormwater pollution more effectively, at lower cost, than by addressing the problem individually. Moreover, we hope that **Island Waters** will serve as a model for communities throughout New England and elsewhere in the U.S.

This report is a foundation for the entire **Island Waters** project. By understanding the status of Island water quality and the work done to date to develop BMPs, we will develop a foundation for identifying and implementing the most beneficial and cost-effective solutions to reduce stormwater pollution to Aquidneck Island's fresh and salt waters.

Why This Matters

Aquidneck Island's surface, ground, drinking, and coastal waters are closely interconnected and highly vulnerable to nutrient and bacterial pollution. Nutrients spur algal blooms, including blooms of potentially toxic cyanobacteria that have appeared in the Island's reservoirs in recent years, increasing threats to both drinking water and recreational waters. Fecal coliform and enterococcus bacteria are indicators of human pathogens – disease-causing organisms that can make people sick when present in swimming or shellfishing waters. Nutrients and bacteria are carried by stormwater from homes, farms, roads, parking lots and public lands into the Island's rivers, streams, reservoirs, and coastal waters.

Water bodies that exceed state pollution standards are classed as "impaired" by the RIDEM. Aquidneck Island's reservoirs are all impaired for nutrients and its principal streams will soon be listed as impaired; groundwater wells also exhibit high levels of nitrates. Coastal waters are locally impaired for nutrients and bacteria, and marine beach closures on the Island typically occur several times over the course of a summer.

The City of Newport, which manages the drinking water system that serves nearly 70,000 residents of Aquidneck Island, has done a great deal in recent years to ensure safe drinking water for all Island reservoirs, including the construction of a state-of-the art water treatment plant at Lawton Valley Reservoir in Portsmouth. However, stormwater runoff is an ongoing stress to the system and must be reduced in order to reduce threats to drinking water, and to maintain the long-term viability and quality of the Island's shared drinking water system.

Since passage of the Clean Water Act in 1972, pollution to Narragansett Bay and other Rhode Island coastal waters has been dramatically reduced, largely due to improved wastewater treatment and the elimination of combined sewer overflows. However, "non-point" sources of pollution such as stormwater have proven more difficult to control and are now a principal source of pollution to coastal waters.

Since stormwater originates from nearly all types of land use on Aquidneck Island – public and private, homes and farms, roads, roofs, parks and parking lots – and affects virtually all of the Island's fresh and salt waters, an integrated approach is needed to effectively and efficiently address the problem. **Island Waters** provides such an approach, in order to ensure that Aquidneck Island's fresh and salt waters continue to serve as the foundation for a healthy environment, prosperous economy and high quality of life – now and in the future.

2 Aquidneck Island Waters

Aquidneck Island, the largest and most populous island in Narragansett Bay, has multiple, interconnected water resources. The Island can be divided into five watersheds or drainage basins (**Figure 2-1**); within these watersheds, water flows into fresh water streams, public water supply reservoirs, and Narragansett Bay (**Figure 2-2**). The interconnected nature of water resource issues on Aquidneck Island highlights the need for regionally coordinated efforts to improve water quality and habitat integrity that the **Island Waters** project is uniquely positioned to address.

2.1 Hydrology - Coastal Waters

Aquidneck Island is located at the southern end of Narragansett Bay. The Island is bounded by the Bay's East Passage on its western shore and the Sakonnet River (which is another passage of the Bay) to its east. The northern end of the Island lies along the shore of Mt. Hope Bay (a sub-estuary of Narragansett Bay), and its southern shore borders Block Island Sound and the Atlantic Ocean. (**Figure 2-1**). Public swimming beaches are located in all three Island communities, but mostly on the southern and eastern shores of the Island.

2.2 Hydrology - Inland Waters

As noted above, Aquidneck Island is made up of five watersheds (**Table 2-1**), all of which drain to Narragansett Bay, the Atlantic Ocean, or the Sakonnet River (**Figure 2-1** and **Figure 2-2**). These larger watersheds contain smaller subwatersheds that drain the area of land contributing to an individual waterbody, such as a lake or stream. A drumlin – a landform composed of dense glacial till - runs along much of Aquidneck Island. This dense till material acts as a horizontal barrier preventing shallow groundwater from infiltrating to a deeper aquifer.

The three municipalities on the Island and Naval Station Newport use water from nine reservoirs owned by the Newport Water System, seven of which are located on Aquidneck Island (**Table 2-2)**. These seven reservoirs fall within three of the five watersheds on the Island (**Figure 2-3**). Each reservoir has its own subwatershed, which includes all of the land and streams that drain to the reservoir. Three main streams flow into four reservoirs: Paradise Brook flows into Nelson Pond, Maidford River flows into both Nelson Pond and then into Gardiner Pond, and Bailey Brook flows into North Easton Pond which is connected via a weir and piping to South Easton Pond. The reservoirs are then interconnected by Newport Water System infrastructure. The subwatersheds that drain to these reservoirs are designated as Surface Water Protection Areas (SWPA) by the Rhode Island Department of Environmental Management (RIDEM) and total 6,524 acres, or 27% of the Island's area. In **Table 2-2**, the size of the resource is presented as length in miles for streams, and acres for lakes and ponds.

Other inland waters that are not part of the public water supply include Founder's Brook, Bloody Brook, Barker Brook, and the Melville Ponds in Portsmouth, Mother of Hope Brook and Little Creek in Middletown, and Almy Pond and Lily Pond in Newport, all of which flow directly to Narragansett Bay or the Atlantic Ocean. During high-flow periods, some of the Maidford River flow, which normally flows into Nelson Pond, also discharges into the Sakonnet River near Third Beach in Middletown.

Table 2-1. Major Watersheds on Aquidneck Island

Name	Location	Size
Upper East Passage Watershed	Portsmouth and Middletown	5,048 acres
Sakonnet River Watershed	Portsmouth and Middletown	8,233 acres
Coastal Aquidneck Watershed	Middletown and Newport	5,924 acres
Lower East Passage Watershed	Portsmouth, Middletown, and Newport	4,210 acres
Mount Hope Bay Watershed	Portsmouth	867 acres

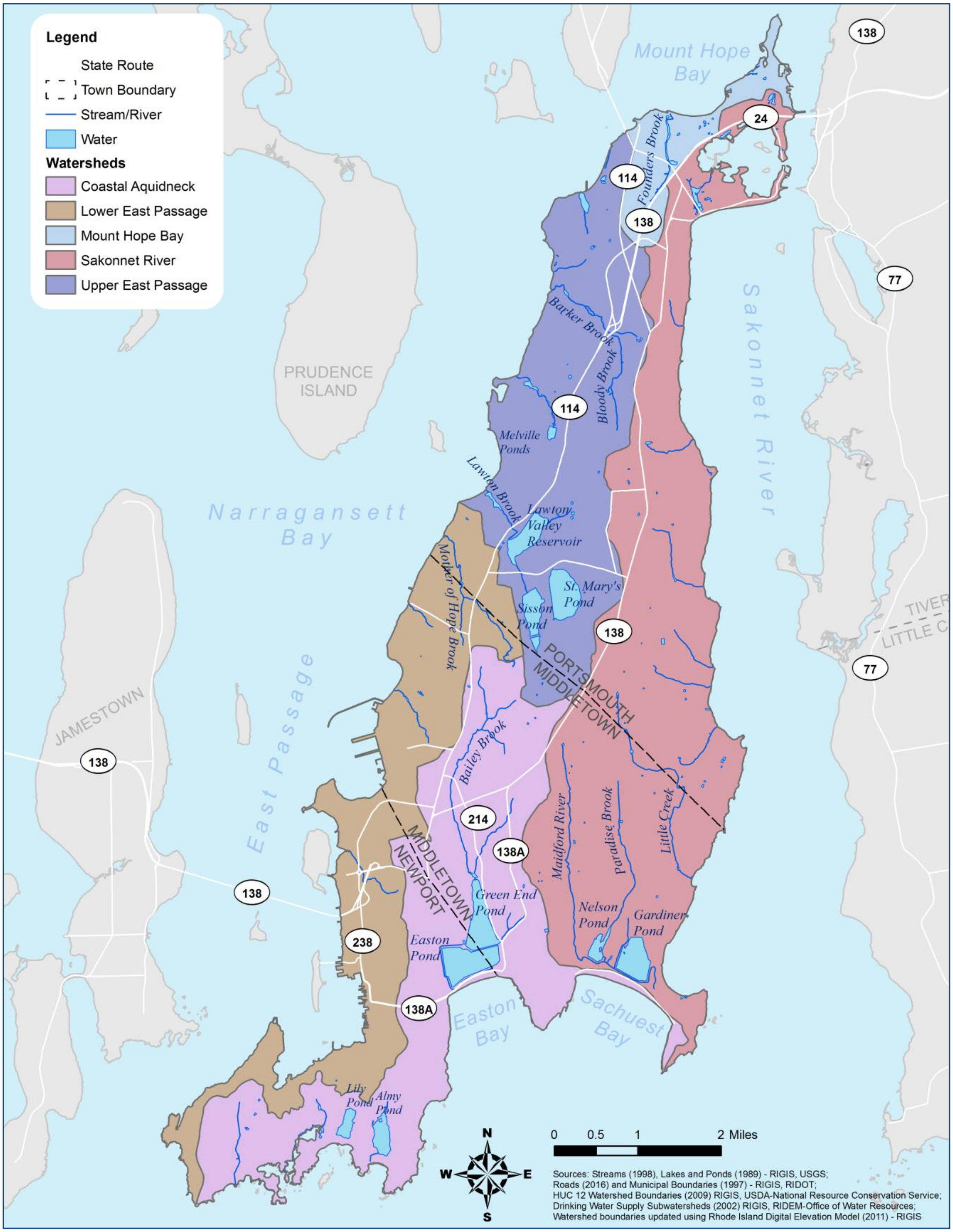

Figure 2-1. Major Fresh Water Lakes, Ponds, and Streams on Aquidneck Island

Table 2-2. Major Freshwater Lakes, Ponds and Streams on Aquidneck Island by Watershed

Name	Location	Size (Pond/Lake) Or Length (Stream)	Water Supply?	Water Quality Impaired?
Upper East Passage Watershed				
Lawton Reservoir	Portsmouth	81 acres	Yes	Yes
St Mary's Pond	Portsmouth	112 acres	Yes	Yes
Sisson Pond	Portsmouth and Middletown	61 acres	Yes	Yes
Melville Ponds	Portsmouth	14.7 acres	No	Yes
Bloody Brook and Barker Brook	Portsmouth	2.9 miles	No	No
Sakonnet River Watershed				
Maidford River	Middletown	4.3 miles	Yes	Yes
Gardiner Pond	Middletown	92 acres	Yes	Yes
Paradise Brook	Middletown	1.8 miles	Yes	Yes
Nelson Pond	Middletown	29 acres	Yes	Yes
Little Creek	Middletown and Portsmouth	3.0 miles	No	No
Coastal Aquidneck Watershed				
Bailey Brook	Middletown	3.7 miles	Yes	Yes
North Easton Pond (Green End Pond)	Middletown and Newport	111 acres	Yes	Yes
South Easton Pond	Middletown and Newport	132 acres	Yes	Yes
Lily Pond	Newport	29.1 acres	No	Yes
Almy Pond	Newport	49.8 acres	No	Yes
Lower East Passage Watershed				
Mother of Hope Brook	Portsmouth and Middletown	2.1 miles	No	No
Mount Hope Bay Watershed				
Founder’s Brook	Portsmouth	1.3 miles	No	No

Lengths and areas calculated from GIS data obtained from RIGIS:
Rivers and Brooks - USGS Hydrolines of Rhode Island (1998),
Ponds and Reservoirs - Lakes and Ponds in Rhode island (1989),
Watersheds and Drinking Water Supply Subwatersheds - Impervious Surfaces (2011), Surface Water Protection Areas (2002)**, and Rhode Island Watershed Boundary Dataset** (2007)

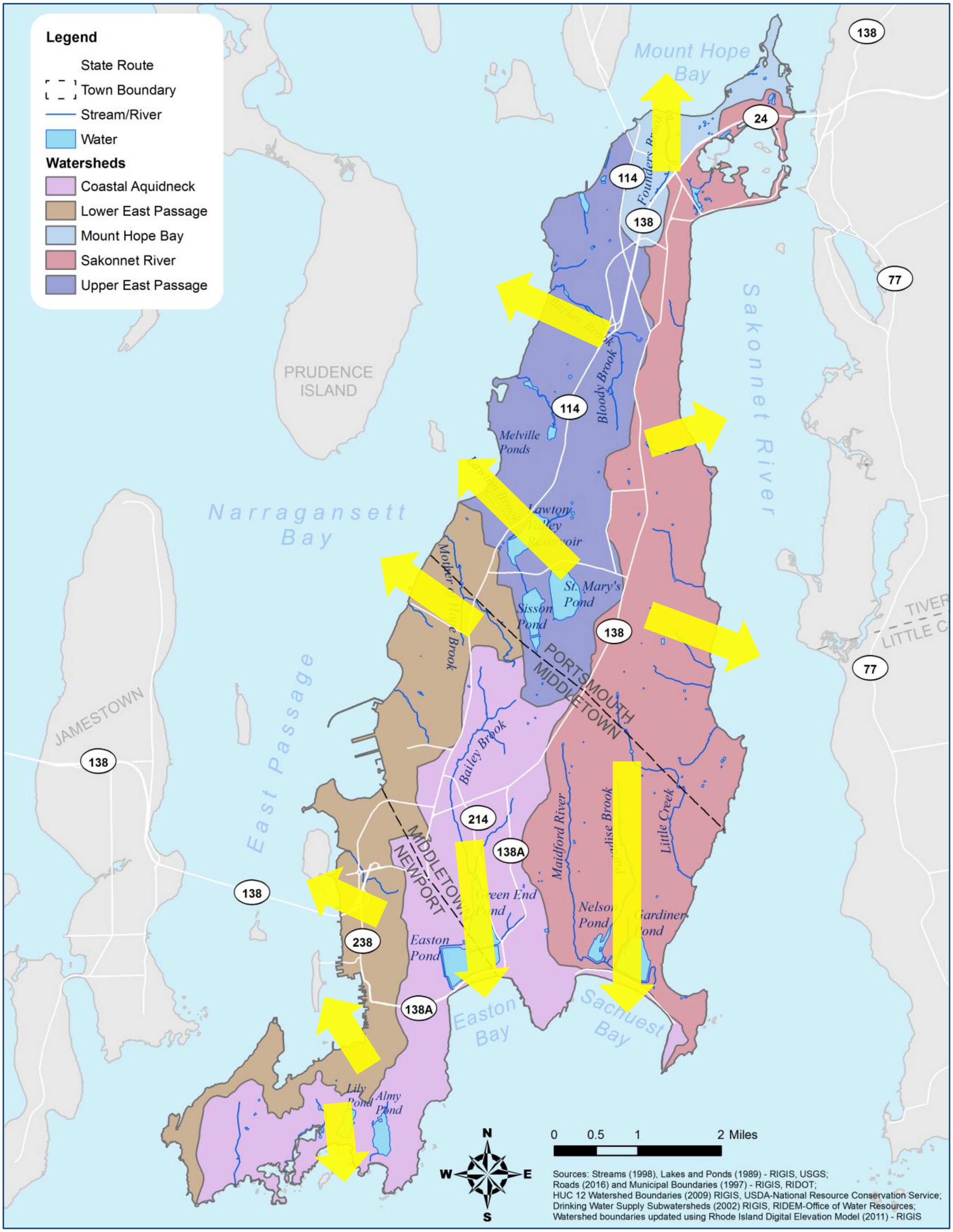

Figure 2-2. Flow Paths in Major Watersheds on Aquidneck Island

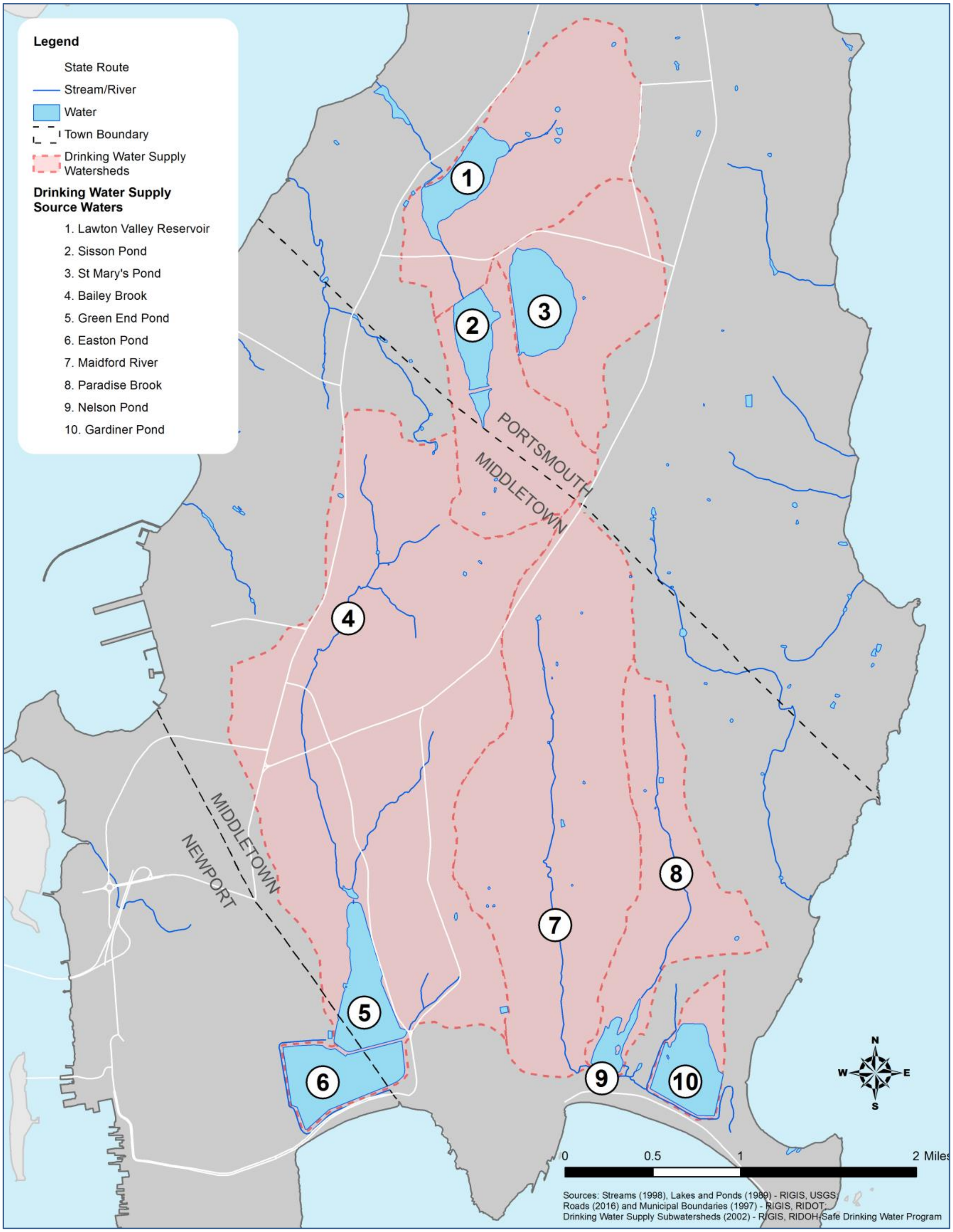

Figure 2-3. Drinking Water Supply Source Waters on Aquidneck Island

2.3 Land Use on Aquidneck Island

Land use has a large impact on water quality. Developed areas, such as residential and commercial land, have a higher proportion of impervious surfaces - surfaces like roads and parking lots that don't allow rainfall to soak into the ground - producing more stormwater runoff that pollutes surface waters and causes local flooding. Land uses associated with fertilizer application, such as agriculture and recreational facilities like golf courses and athletic fields, and uses potentially associated with erosion and animal waste, such as pasture land, are also likely to have a negative impact on water quality.

Land use on Aquidneck Island is diverse, ranging from forested and agricultural uses to high-density residential and commercial uses (**Figure 2-4**). Across the Island, residential land of variable density represents the single largest land use (36%), followed by forest and brushland (17%), agricultural (12%) and commercial (5%) land. This proportional mix of land use varies by watershed and by drinking water supply subwatershed. The Mount Hope Bay watershed in Portsmouth is more than 50% residential land, with the remainder dominated by forest (11%), and recreational facilities (10%). By contrast, the Sakonnet River watershed matches the Island-wide proportion of residential land (36%), but contains a higher proportion of agricultural land (22%) and pasture (8%).

Within the subwatersheds that contain drinking water supplies, there are two predominant mixes of land use (**Table 2-3**). Bailey Brook is dominated by residential and commercial land (approximately 50%). The Maidford River, Nelson Pond, and St. Mary's Pond watersheds are a mix of residential (23%-33%) and agricultural land (28%-34%). The Green Valley Country Club also straddles the watershed boundary between the Lawton Reservoir and St. Mary's Pond watersheds, which accounts for the land use devoted to recreation. In the Maidford River watershed, pasture land (12%) and agricultural land (34%) combined account for a substantial amount of land use.

Table 2-3. Land Use Within Drinking Water Supply Subwatershed* by Percentage of Subwatershed Area

Land Use	Bailey Brook	Gardiner Pond	Lawton Reservoir	Maidford River	Nelson Pond	St Mary's Pond
Residential	34.3	1.6	32.2	33.4	23.5	23.0
Commercial	16.8	0.8	0.5	0.9	0.1	0.0
Recreation	2.2	0.0	11.3	2.4	0.3	7.7
Agriculture	9.3	8.8	16.2	34.3	28.3	28.9
Pasture	1.0	4.0	2.7	12.2	6.2	1.8
Forest	10.5	15.4	21.7	12.9	31.1	16.5
Other	25.9	69.4**	15.4	3.9	10.5	22.1

*Values calculated based on Surface Water Protection Areas designated by RIDEM. Does not include coastal watersheds.

**Area occupied by Gardiner Pond makes up 68% of the Gardiner Pond subwatershed

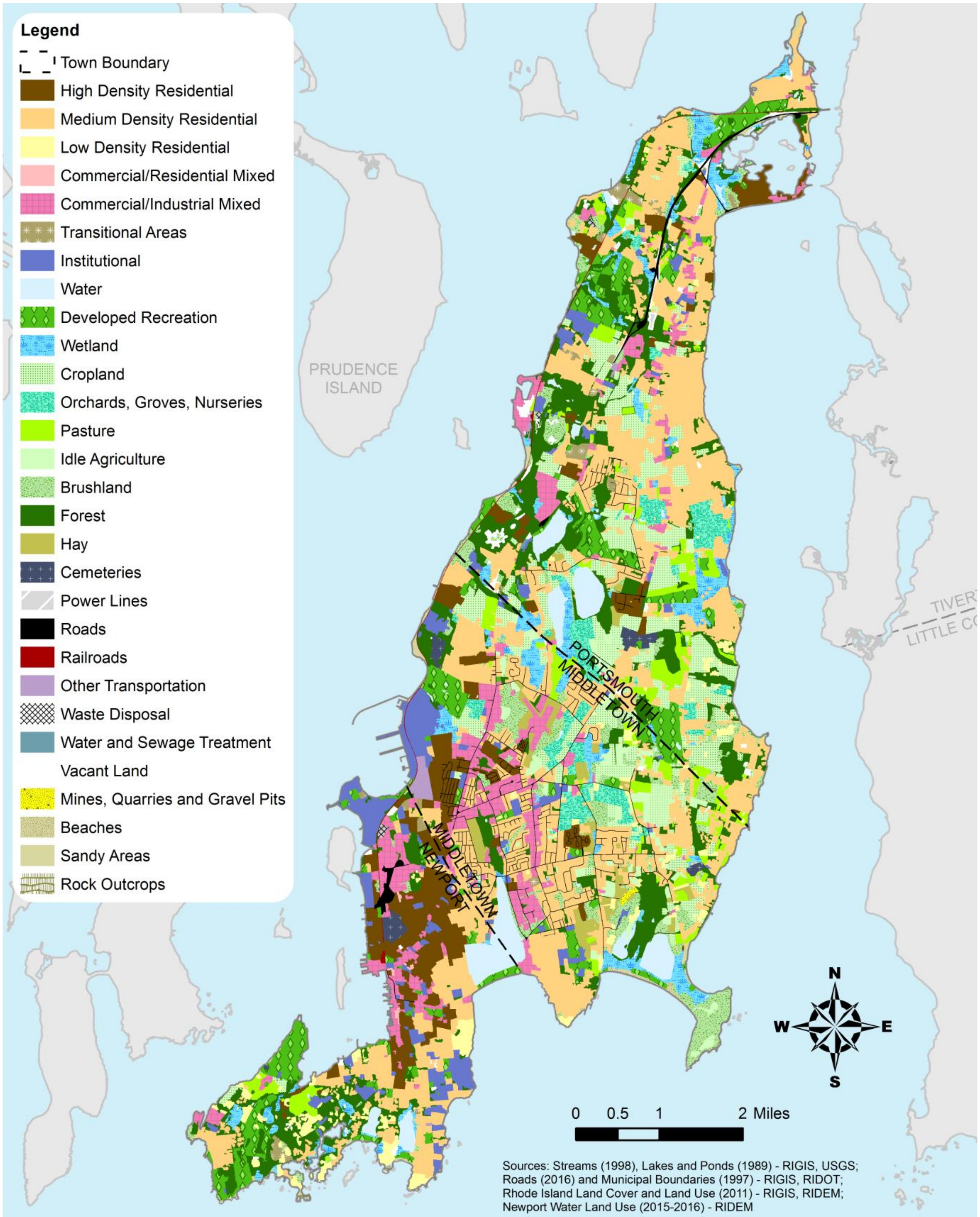

Figure 2-4. Land Use in Aquidneck Island Watersheds

Impervious Cover

Impervious cover (IC) is any land surface covered by asphalt, concrete, brick, or similar material that does not allow rainwater to infiltrate into the soil. Roads, parking lots, sidewalks, driveways, and roofing, among others, are examples of IC. Rainwater that falls on IC runs off and is typically captured by stormwater infrastructure and directed to surface water bodies, or drains directly to surface water bodies like streams and ponds, which on Aquidneck Island are the sole sources of drinking water. The percentage of land surface covered by IC is a useful metric or indicator for examining the impact of urbanization on the health of freshwater systems and water supplies (Allan, 2004).

The greater the area of land covered by impervious surfaces, the greater the amount of runoff volume generated during rainfall. This runoff picks up and contains whatever is on the land surface, such as nutrients, sediments, salts, and heavy metals. Stream temperature has also been shown to increase with impervious cover (Galli, 1991) in the stream's watershed. Increases in IC and the associated increases in contaminants carried by runoff also negatively impacts the habitat within streams. In watersheds where impervious cover exceeds 10%, rivers and streams generally exhibit degraded water quality; where impervious cover exceeds 25%, surface water quality tends to be poor, and flooding is much more frequent than in less developed watersheds (Schueler et al., 2009).

Figure 2-5 shows impervious cover on Aquidneck Island. On Aquidneck Island, impervious cover in watersheds that drain directly to drinking water supplies is below the 10% degradation threshold for Gardiner, Nelson, and St. Mary's Ponds, higher than the 10% threshold for the Lawton Reservoir and Maidford River, and greater than the 25% threshold for Bailey Brook. On a broader scale, all watersheds on Aquidneck Island are above the 10% impact threshold, and the Lower East Passage, Mount Hope Bay and Coastal Aquidneck subwatersheds are beyond the 25% threshold. Mount Hope Bay is almost at the 25% threshold.

Table 2-4. Impervious Cover by Major Watershed

Major Watershed	Impervious Cover (%)
Upper East	15.3
Sakonnet River	14.4
Lower East	37.7
Coastal	28.8
Mount Hope Bay	24.3

Table 2-5. Impervious Cover within Drinking Water Supply Subwatershed

Subwatershed	Impervious Cover (%)
St Mary's Pond	8.2
Maidford River	11.9
Nelson Pond	7.2
Gardiner Reservoir	1.1
Lawton Reservoir	10.4
Bailey Brook	30.1

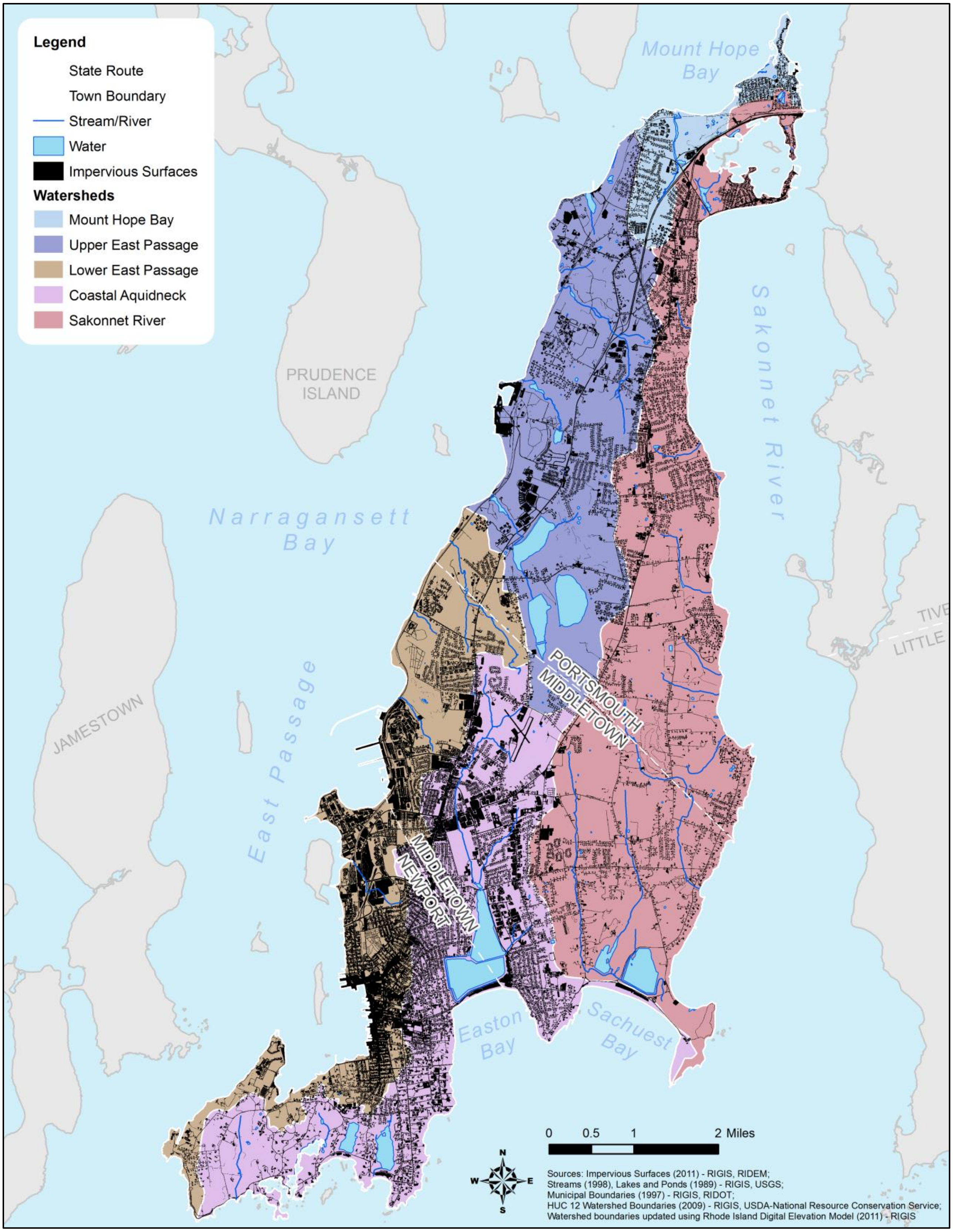

Figure 2-5. Impervious Cover on Aquidneck Island

2.4 Water Quality

Water quality can be assessed in terms of standards established at both the state and federal level to protect public health and environmental quality. In Rhode Island, water quality regulations and the combined sewer overflow policy are based on federally promulgated water quality standards for Clean Water Act (CWA) purposes.

Under Section 303d of the CWA, Rhode Island and other states, territories, and authorized tribes must develop lists of impaired waters, which are waters that fail to meet one or more water quality standards applicable to their classification and designated use(s). This list has been compiled biennially since 1998 by RIDEM's Office of Water Resources, with the most recent version published for 2014.

The Impaired Waters List is a useful way to approach water quality issues based on established standards, especially for inland waters on Aquidneck Island, as well as the coastal waters that surround it. The quality of waters upstream of the Island's beaches is also linked to beach closures. Based on the most recent draft of the Impaired Waters List, in 2014, all seven of the Island's drinking water supply reservoirs were listed as impaired (**Figure 2-7**). The primary causes of the impairments are total phosphorus, total organic carbon, and bacteria (**Table 2-6**). Bailey's Brook and Maidford River, which feed multiple reservoirs, were listed in 2011 as impaired by enterococcus and fecal coliform and continue to be identified as impaired.

2.4.1 Impaired Waters

RIDEM designates waters that fail to meet quality standards as impaired and submits this list of waters to the U.S. Environmental Protection Agency (EPA) for approval every two years. Impaired waters must be assigned a Total Maximum Daily Load (TMDL), or a set amount of a pollutant that is allowed to enter per day, in order to reduce pollutant concentration for that water below established pollutant thresholds. TMDLs are developed by RIDEM according to a priority list that incorporates the level of exceedance and the sensitivity of uses of the water to the impairment.

Nutrients and Carbon

Total phosphorus (TP) and total organic carbon (TOC) are the principal pollutants causing impaired water quality in Aquidneck Island's drinking water reservoirs and other fresh waters. Freshwater ponds and streams are naturally low in phosphorus. This lack of phosphorus limits the growth of algae, which need phosphorus to grow and produce organic carbon. Phosphorus is a nutrient that can come from septic systems, sewage, animal waste, lawn fertilizer, road and construction erosion, automobile and power plant emissions (via atmospheric deposition), and other human and natural sources. The Rhode Island water quality nutrient criteria for freshwater ponds and their tributaries is an annual or seasonal average of 0.025 mg/l. 2011-2012 water quality sampling conducted by Fuss & O'Neill at all Newport Water Supply reservoirs showed no sampling locations consistently below the nutrient criteria, indicating chronically elevated TP levels.

Analysis of RIDEM water quality testing data collected in 2015, which was undertaken to support the development of TMDLs for the drinking water supplies, indicated that average total phosphorus concentrations of 0.025 mg/l were exceeded at each reservoir on Aquidneck Island (**Figure 2-6**). A 2017 water quality report from RIDEM found dry-weather total phosphorus levels in Maidford River were within quality criteria, but half of samples from Paradise Brook exceeded criteria (RIDEM, 2017). Wet-weather sampling for total phosphorus yielded TP concentrations 10- to 30-times greater than 0.025 mg/l in Maidford River and 55-times greater in Paradise Brook (RIDEM, 2017).

TP is also a concern because of its link to alga blooms (also see the **Cyanobacteria** section below). When phosphorous and other nutrients run off the land into the water, they spur the growth of algae which in turn increases ambient levels of TOC. TOC is a concern because when drinking water supplies are treated by chlorination, certain chlorinated hydrocarbons, such as chloroform, can result. At sufficient concentrations, these compounds can be dangerous to human health. The Newport Water System follows all RIDOH water quality testing protocols to ensure the safety of the water it delivers to customers.

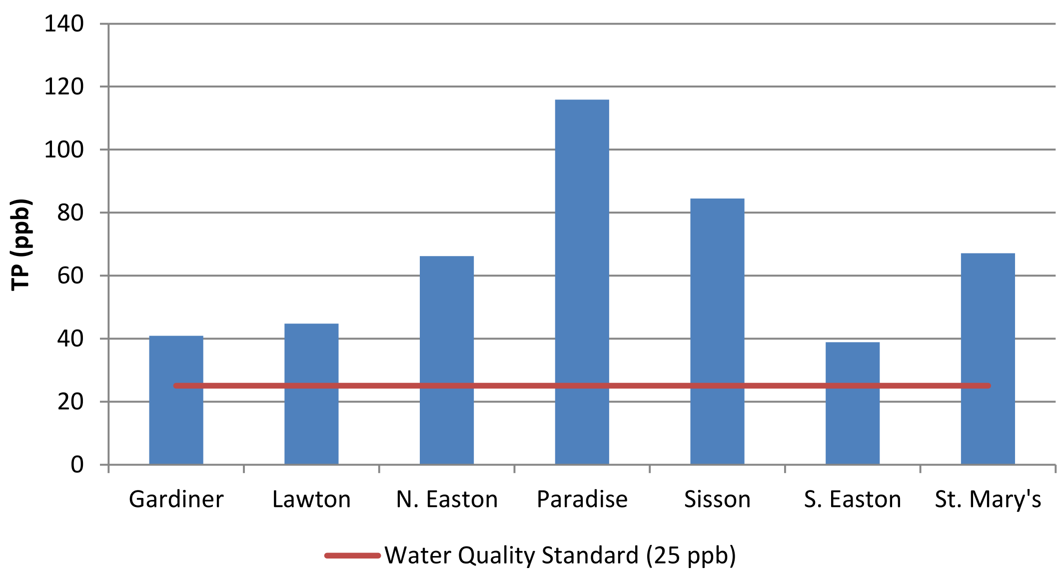

Figure 2-6. Seasonal Average Total Phosphorus (TP) Concentrations Relative to Water Quality Standards – Data Collected by RIDEM Spring-Fall 2015

Although none of the freshwaters on Aquidneck Island are impaired due to nitrogen, concentrations of this nutrient are of concern for both fresh and marine waters. Traditionally, pollution prevention and nutrient management have focused on controlling either phosphorus or nitrogen as the single “limiting nutrient” (i.e., the one that limits the growth of algae and aquatic plants), assuming that nitrogen is the limiting nutrient in marine waters and phosphorus the limiting nutrient in fresh waters. For that reason, reduction of nitrogen discharge into marine waters, like Narragansett Bay, has been identified as an important action to improve and protect coastal water quality. However, control of both nutrients is important for fresh waters. Recent research has shown that controlling nitrogen is also important for limiting harmful algal blooms in fresh waters and that there is evidence of a link between algal toxins and conditions where nitrogen is disproportionately available relative to phosphorus (Paerl and Otten, 2013; USEPA, 2015). As a result, reducing both phosphorus and nitrogen pollution is important for protecting water quality on and round Aquidneck Island.

Bacteria

Both the Maidford River and Bailey's Brook are listed as impaired for fecal coliform and enterococcus, respectively. Fecal coliform and enterococcus are fecal indicator bacteria, used as a surrogate for measuring fecal pollution, which can originate from human and animal waste. Elevated levels of bacteria indicate the potential for pathogens that can threaten human health.

Rhode Island water quality standards for freshwaters requires that the terminal reservoir of a drinking water supply not exceed a geometric mean value for fecal coliform of 20 MPN/100 ml[1] and that not more than 10% of the samples exceed a value of 200 MPN/100 ml.

The less restrictive primary contact recreation standard require that the geometric mean of fecal coliform not exceed 200 MPN/100 ml and that not more than 10% of the samples exceed 400 MPN/100 ml. Enterococcus concentrations are not to exceed a geometric mean of 33 CFU/100ml at a bathing beach or 54 CFU/100 ml in non-bathing waters, with a maximum allowable single sample concentration of 61 CFU/100ml.

A RIDEM water quality study of Maidford River and Paradise Brook, which feed water supply reservoirs, found that exceedances of water quality criteria were strongly linked with stormwater (RIDEM 2017). Wet-weather sampling in both streams revealed a geometric mean concentration of a minimum of 25-times the criteria for both fecal coliform and enterococcus.

Cyanobacteria

Cyanobacteria, also incorrectly but commonly called blue-green algae, are of concern for water supplies and recreational waters due to taste and odor concerns, the undesirable aesthetic appearance associated with blooms or scums of cyanobacteria, and their potential to carry cyanotoxins, such as microcystins, that threaten public health. Although the presence of a bloom does not necessarily indicate the presence of cyanotoxins, the blooms have become known as harmful algal blooms or HABs. These blooms contribute to the organic carbon pool within a water body and subsequently increase the potential for formation of disinfection by-products during the water treatment process.

[1] CFU and MPN are equivalent measures of bacterial density in a sample. CFU stands for colony forming units and MPN stands for most probable number of CFUs. These two measures use different methodologies to estimate density. Where CFU estimates come from direct counts of bacterial growth, MPN values result from statistical estimation. MPN may be more appropriate for low densities in water (Blodgett 2010).

The Rhode Island cyanobacteria monitoring program, jointly administered by the RIDEM and the Rhode Island Department of Health (RIDOH) was developed in 2010 to screen for, respond to, and characterize harmful algal blooms in the state's fresh waters. Recreational advisories are triggered if one or more conditions are met: when the cyanobacteria cell count exceeds 70,000 cells/mL, microcystin-LR level of lysed (destroyed) cells is 14 µg/L or higher, or there is a visible scum, mat or lake/pond wide bloom.

The EPA has recently proposed draft criteria for human health recreational ambient water quality criteria and/or swimming advisories for two common cyanotoxins (cylindrospermopsin and microcystins). This draft guidance proposes a microcystin criteria of 4 ug/l. RIDEM and RIDOH are considering replacing the current microcystin criteria of 14 ug/l with the EPA recommended 4 ug/l microcystin criteria.

RIDOH Laboratories developed the capacity to analyze water samples for various cyanotoxins, including microcystin, in 2014. Between 2015 and 2016, RIDEM submitted samples from waterbodies on Aquidneck Island to the RIDOH laboratory for toxin analysis. In both 2015 and 2016, thirty-five samples each were submitted from waterbodies located on Aquidneck Island. In 2015, of those 35 samples submitted, only two contained microcystin levels above the detection limit (1.0 ug/l). These levels were 1.5 and 2.5 ug/l. In 2016, ten of the 35 samples submitted exhibited microcystin levels above the detection limit of 1.0 ug/l and ranged from 3.9 to 120 ug/l.

In 2015, the EPA published drinking water health advisories for microcystins, at concentrations of 0.3 ug/l for infants and 1.6 ug/l for children and adults. In 2014 RIDOH required all drinking water suppliers to sample both raw water intake and finished water for microcystin on a weekly basis from April through October. Results from the Newport Water Supply showed no detections of toxins in the finished water. Two samples from raw water intake showed levels of toxins between 1-2 ug/l.

Although on Aquidneck Island only North Easton Pond is currently listed as impaired due to excessive algal growth, the presence of cyanobacteria – resulting at least in part from excess total phosphorus – are a water quality concern across Aquidneck Island. The identification of the other drinking water supply reservoirs on Aquidneck Island as impaired due to phosphorus and total organic carbon are related to the presence of cyanobacteria blooms in those water bodies.

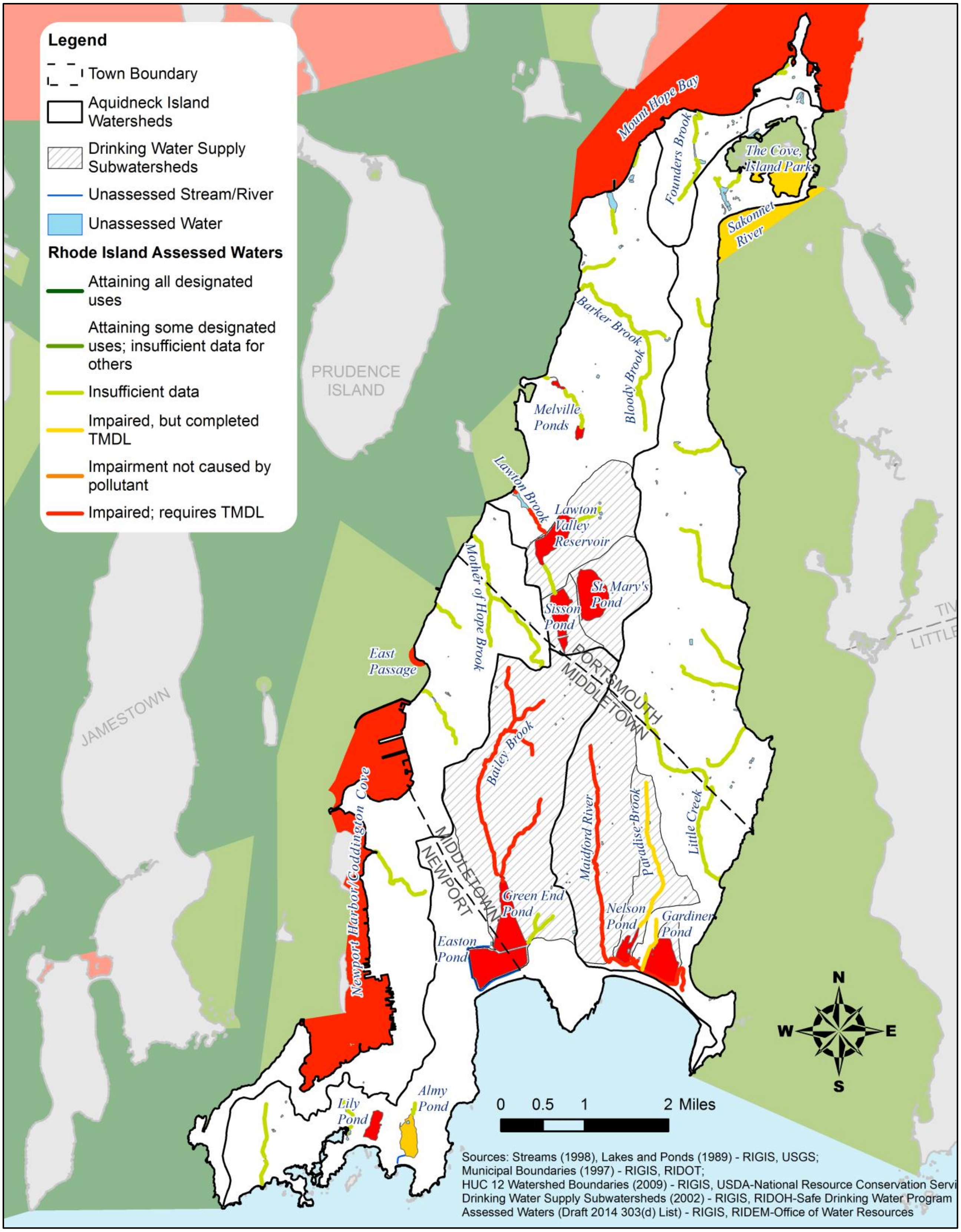

Figure 2-7. Status of Island Waters Relative to Designated Uses (RIDEM 2015)

2.4.2 Beach Closures

The Rhode Island Department of Health is responsible for the licensing and regulation of bathing beach facilities in the State of Rhode Island, including both fresh and saltwater beaches. RIDOH uses the concentration of the fecal indicator bacteria enteroccocus to determine when to close public access to beaches to protect the public from illness associated with swimming in contaminated bathing waters. RIDOH has determined that beaches in Rhode Island must close when enterococcus levels in freshwater or saltwater reach a concentration of 60 colony forming units per 100 mL of water (CFU/100 mL).

Enterococcus is used as an indicator of human fecal pollution because of its ubiquity in human feces and persistence in the environment. Enteroccocus are also found in animal waste from livestock operations, agricultural operations using manure as fertilizer, and pet and wildlife waste. Enteroccocus concentrations are used as a water quality standard for recreational waters because of the established association between enterococcus concentrations and swimmer health in recreational marine waters (Wade et al, 2003). These indicator bacteria, as well as other pathogens for which they are a surrogate, are transported by stormwater during rain events into inland waters by overland flow and stormwater infrastructure. Stormwater discharged to inland waters that drain near beaches have the potential to contribute to exceedances of recreational water quality standards. RIDOH has determined that beach closures across the state are closely related to precipitation events (RIDOH, 2017).

Although swimming, kayaking, surfing, and fishing are recreational activities that occur at many locations, the State of Rhode Island officially monitors and reports on water quality samples collected at licensed beaches throughout Rhode Island (**Figure 2-8**) during the "beach season," which extends from Memorial Day in late May through Labor Day in early September. The graphs in **Figure 2-9** show the number of days of beach closure during the past 5 years (2012-2016) at licensed beaches on Aquidneck Island which experienced closures. In the approximately 100-day long beach season, none of the licensed beaches on Aquidneck Island have experienced more than a 10% closure rate in any given year; no beach has been closed for more than 8 days in any given year. Because of the relationship between precipitation, stormwater runoff and elevated bacteria levels at beaches and other coastal recreational areas, actions that reduce both potential sources of bacteria and their transport via stormwater runoff will benefit public health by reducing exposure to potential pathogens.

Figure 2-8. State-Licensed Beaches on Aquidneck Island

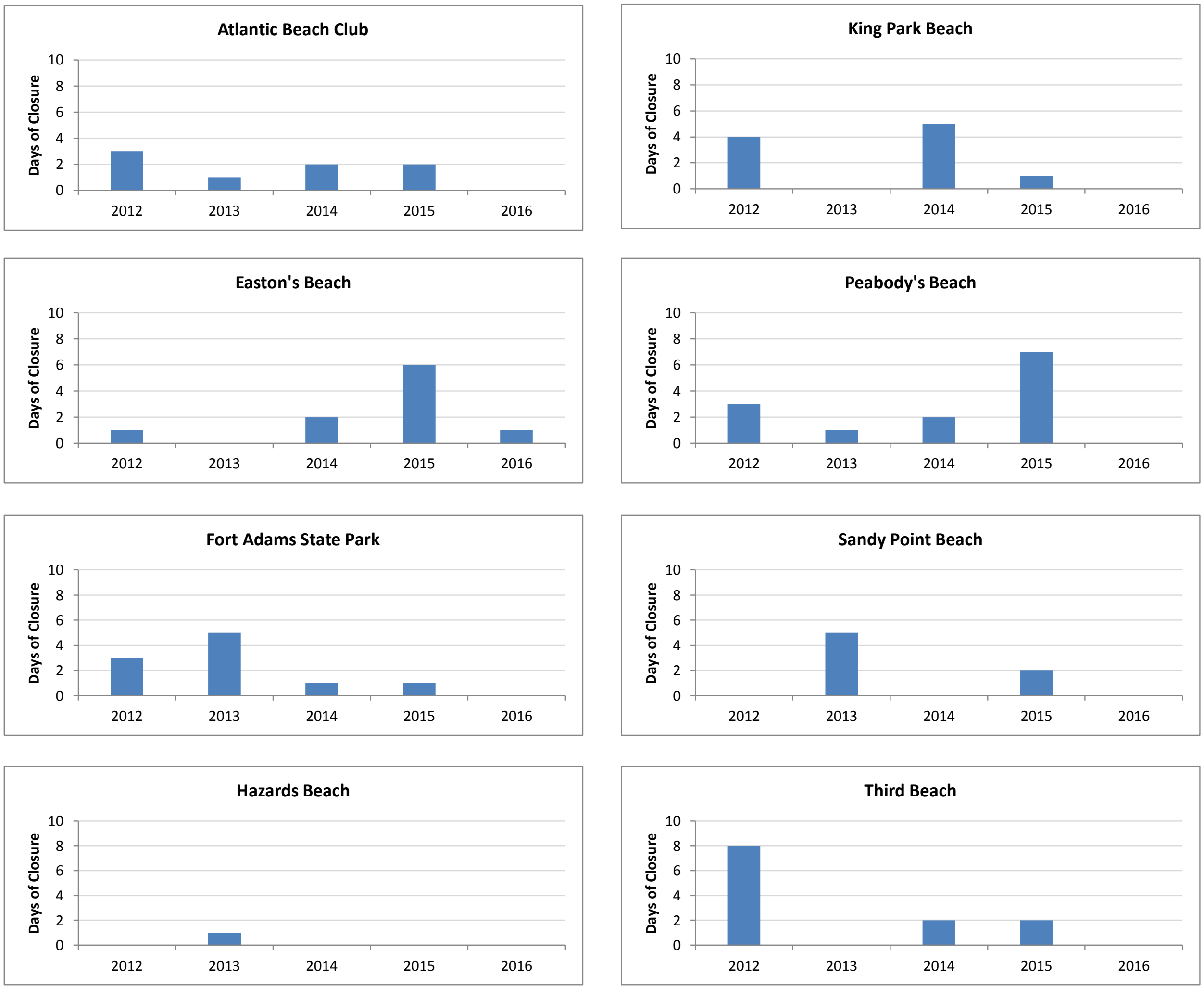

Figure 2-9. Days of Reported Beach Closures on Aquidneck Island 2012-2016 (RIDOH, 2017)

2.4.3 Shellfish Area Closures

RIDEM classifies shellfish areas in state waters by their suitability for cultivation of consumable shellfish, such as clams, mussels, and oysters. Growing areas are tested on a regular basis to determine updates to shellfishing classification. The RIDEM Office of Water Resources routinely monitors marine phytoplankton in Rhode Island's shellfish growing waters and, as necessary, establishes closures to ensure that shellfish harvested from Rhode Island waters are free of natural biotoxins and meet all health standards. Around Aquidneck Island, growing areas are considered either approved or prohibited, with the exception of Gooseneck Cove, which is not tested and is prohibited as a preventative measure. Despite the designation of legal shellfishing areas, some illegal shellfishing is also likely occurring.

Shellfish are filter feeders. This term indicates that they feed by passing water over a filtering appendage and eating anything caught in the filter. Their main diet is algae, but the filter also traps bacteria. In impaired waters, bacteria such as enterococcus and fecal coliform are caught in the filter. Human consumption of contaminated shellfish can cause gastrointestinal illness.

Waters are closed to shellfishing if fecal coliform levels are found in excess of established standards, and/or actual or potential pollution sources are found to be discharging into shellfishing waters and could potentially cause unacceptable bacteria levels in adjacent waters. Often, closure areas are associated with wastewater treatment plant outfalls (i.e., Mount Hope Bay), more-developed areas with greater impervious cover and near stormwater outfalls, or near agricultural operations. As with recreational areas, measures to reduce bacteria and pathogens at their source and prevent them from being introduced to coastal waters via stormwater runoff will help to protect current shellfishing areas.

A complete legal description of the precise boundaries of prohibited areas is maintained by RIDEM's Office of Water Resources. Briefly, the northern end of the island is prohibited as is Newport Harbor and the area south of Easton Pond. Most of the Sakonnet River is approved for shellfishing (**Figure 2-10**).

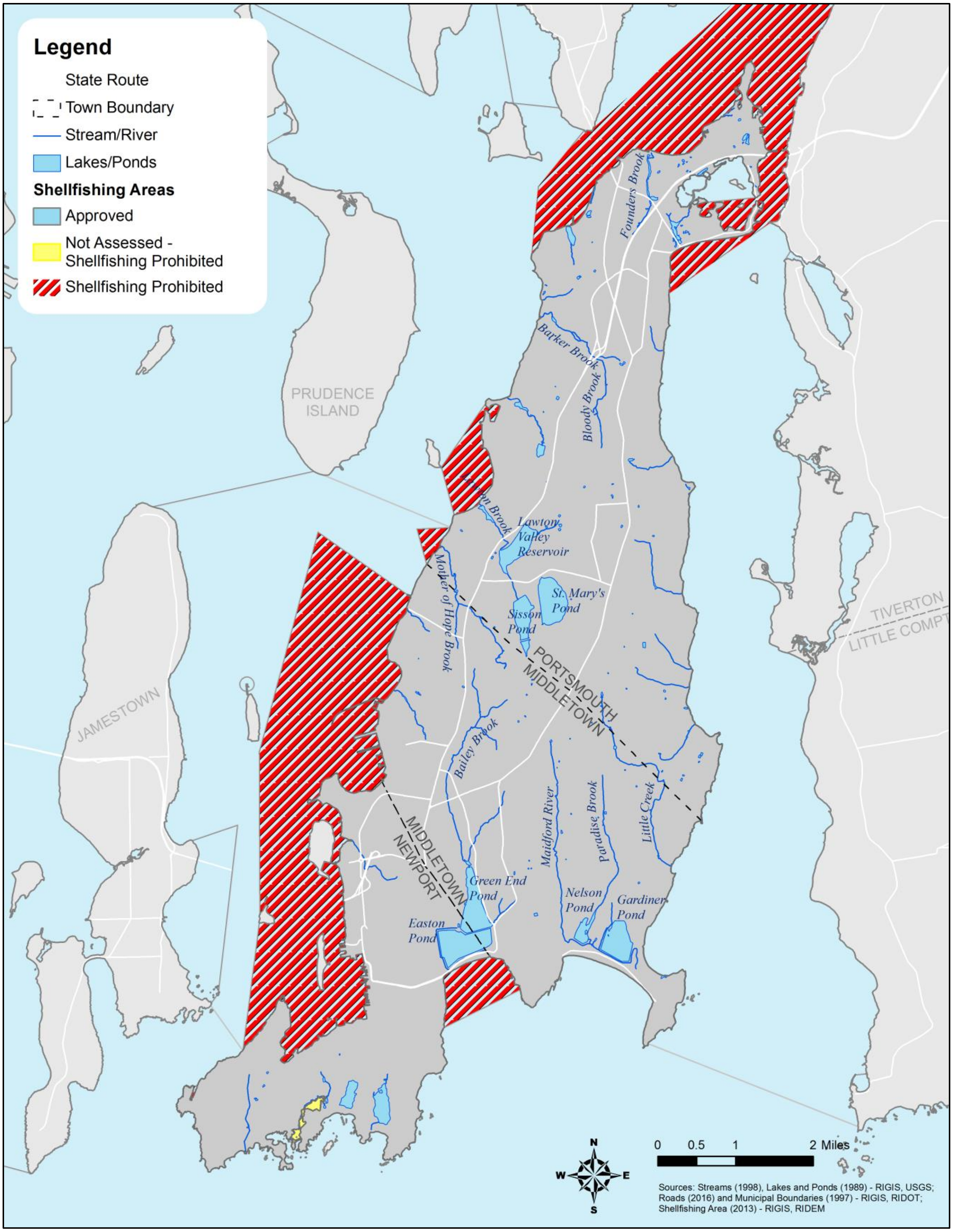

Figure 2-10. Shellfishing Areas

2.4.4 Conclusions

While Aquidneck Island provides safe drinking water, coastal and inland recreational waters for swimming and fishing, and shellfishing areas, these valuable water resources are under pressure from a combination of factors. Some factors are impossible or difficult to control, such as the capacity of native soils to capture and infiltrate runoff, the changing frequency and intensity of rainfall events, or the growing population on the Island. Others are the result of human action and can be influenced to some degree through a combination of behavioral changes (e.g. reducing lawn fertilization, managing pet and livestock waste) and landscape and engineering controls that reduce the impact of impervious surfaces and pollutant transport to fresh waters on the Island and marine waters that surround the Island.

The primary pollutants that drive impairment in the Island's fresh waters and impact coastal are typical for developed areas – nutrients and bacteria (**Tables 2-6 and 2-7**). They reflect the influence of a developed landscape and activities on that landscape. In addition, nutrients have the potential to create a cascade of water quality issues in the Island's fresh water reservoirs by fueling cyanobacteria blooms that in turn create the potential for both the presence of algal toxins and increased the amount of total organic carbon in drinking water supplies and increase the potential for formation of disinfection by-products during water treatment processes.

Previous watershed studies of St. Mary's Pond, Maidford River, and Bailey Brook watersheds (Fuss & O'Neill 2013, 2016a,b, 2017) identified impervious cover and runoff from residential and agricultural land uses as primary sources of water quality impairment on the Island. The elevated amount of impervious cover and lawn fertilizer application in the Bailey Brook watershed appears linked with increased bacterial loads and total phosphorus concentrations in North and South Easton Ponds. The levels of phosphorus elsewhere in water supply reservoir subwatersheds relate to agricultural activities, such as nurseries and row crops, and lawn fertilizer application on recreational and residential areas and commercial and institutional properties.

To date, several studies have assessed issues impacting Aquidneck Island water resources and proposed solutions to address existing impairment and prevent further impact to water quality in individual water bodies or subwatersheds. In general, stormwater management has come to the forefront as a strategy for resource protection and restoration which is why understanding existing municipal stormwater management (**Section 3**) is part of a comprehensive look at the status of **Island Waters**. **Section 4** of this report summarizes the work previously done to identify opportunities for stormwater management and subsequent pollution reduction on the Island. Because of the interconnectedness of both the water resources and the pollution sources, consideration of Aquidneck Island as a whole is needed to yield the most beneficial yet sustainable solutions to address lasting improvement to and protection of water resources. **Section 5** introduces a prioritization approach to stormwater management to address stormwater quality on the Island, taking into consideration environmental conditions, the performance and characteristics of stormwater management measures, and community factors.

Table 2-6. Impaired Fresh Waters on Aquidneck Island*

Name (Waterbody Classification) Municipality	Waterbody ID	Use Description	Cause/Impairment
Upper East Passage Watershed			
Lawton Valley Reservoir (AA) Portsmouth	RI0007035L-06	Fish and Wildlife Habitat	Flow regime alterations
		Drinking Water Supply	TP** TOC**
Saint Mary's Pond (AA) Portsmouth	RI0007035L-05	Fish and Wildlife Habitat	Flow regime alterations
		Drinking Water Supply	TP TOC
Sisson Pond (AA) Portsmouth	RI0007035L-10	Fish and Wildlife Habitat	Flow regime alterations
		Drinking Water Supply	TP TOC
Lawton Brook (A) Portsmouth	RI0007035R-04	Fish and Wildlife Habitat	Benthic – Macroinvertebrate Bioassessments
Melville Ponds (A) Portsmouth	RI0007029L-01	Fish and Wildlife Habitat	TP
Sakonnet River Watershed			
Nelson Paradise Pond (AA) Middletown	RI0007035L-02	Fish and Wildlife Habitat	Flow regime alterations
		Drinking Water Supply	TP TOC
Gardiner Pond (AA) Middletown	RI0007035L-01	Fish and Wildlife Habitat	Flow regime alterations
		Drinking Water Supply	TP TOC

Name (Waterbody Classification) Municipality	Waterbody ID	Use Description	Cause/Impairment
Sakonnet River Watershed			
Maidford River (AA) Middletown	RI0007035R-02A	Fish and Wildlife Habitat	Benthic – Macroinvertebrate Bioassessments
			Lead
		Contact Recreation	Fecal Coliform
Maidford River (AA) Middletown	RI0007035R-02B	Fish and Wildlife Habitat	Benthic – Macroinvertebrate Bioassessments
		Contact Recreation	Fecal Coliform
Coastal Aquidneck Watershed			
North Easton Pond (Green End Pond) (AA) Middletown, Newport	RI0007035L-03	Fish and Wildlife Habitat	Excess Algal Growth
			Flow regime alterations
		Drinking Water Supply	TP
			TOC
South Easton Pond (AA) Newport)	RI0007035L-04	Fish and Wildlife Habitat	TP
		Drinking Water Supply	TOC
Bailey's Brook (AA) Middletown	RI0007035R-01	Fish and Wildlife Habitat	Benthic – Macroinvertebrate Bioassessments
			Lead
		Contact Recreation	Enterococcus
Lily Pond (A) Newport	RI0010047L-02	Fish and Wildlife Habitat	Non-native Aquatic Plants
			TP

* Information from State of Rhode Island 2014 303(d) List of Impaired Waters

** TP – Total Phosphorus, TOC – Total Organic Carbon

*** TMDL not required

Table 2-7. Impaired Marine Waters Around Aquidneck Island*

Name (Waterbody Classification) Municipality	Waterbody ID	Use Description	Cause/Impairment
Mount Hope Bay			
Mt. Hope Bay (SA) Warren, Portsmouth	RI0007032E-01A	Fish and Wildlife Habitat	Fish Bioassessments*** Nitrogen (Total) Oxygen, Dissolved Temperature, Water***
Mt. Hope Bay (SB) Portsmouth, Tiverton	RI0007032E-01C	Fish and Wildlife Habitat	Fish Bioassessments*** Nitrogen (Total) Oxygen, Dissolved Temperature, Water***
		Contact Recreation	Fecal Coliform
Lower East Passage			
Newport Harbor Coddington Cove (SB) Newport, Middletown	RI0007030E-01A	Fish and Wildlife Habitat	Sediment Bioassays for Estuarine and Marine Water
	RI0007030E-01D	Fish and Wildlife Habitat	Sediment Bioassays for Estuarine and Marine Water
	RI0007030E-01E	Contact Recreation	Enterococcus
East Passage (SA) Middletown	RI0007029E-01C	Fish and Wildlife Habitat	Sediment Bioassays for Estuarine and Marine Water
		Contact Recreation	Sediment Bioassays for Estuarine and Marine Water
		Shellfish Consumption	Sediment Bioassays for Estuarine and Marine Water

* Information from State of Rhode Island 2014 303(d) List of Impaired Waters

*** TMDL not required

3 Current MS4 Programs

The Rhode Island Department of Environmental Management (RIDEM) Municipal Separate Storm Sewer System (MS4) stormwater general permit was developed pursuant to EPA's Stormwater Rule. Stormwater permits in Rhode Island are issued under the authority of the National Pollutant Discharge Elimination System (NPDES) and Rhode Island General Laws Chapter 46-12, 42-17.1, and 42-35, as amended.

In 1990, Phase I of the U.S. Environmental Protection Agency's (EPA) stormwater program was promulgated under the Clean Water Act (CWA) and focused on medium and large MS4s that generally serve populations of 100,000 or more, large scale construction activity, and some categories of industrial activity. EPA's Phase II program expanded the Phase I program by requiring MS4s in Urbanized Areas (defined below) not subject to Phase I, as well as small construction activity, to also implement programs and practices to control polluted stormwater runoff. RIDEM first issued the MS4 General Permit in December 2003 under the "Phase II Rule." The RI MS4 permit has been extended, without modifications, since 2008, when it was originally scheduled to expire. The purpose of the MS4 General Permit is to protect waters of the state from urban stormwater runoff through municipal separate storm sewer systems. Urban stormwater runoff is often a leading cause of water quality impacts to surface waters in Rhode Island and nationally.

EPA defines a regulated small MS4 as a municipality that owns and operates a storm sewer system in an Urbanized Area (UA). Urbanized Areas are defined by the federal Census Bureau and consist of densely populated areas surrounding urban centers that have a population density of more than 1,000 per square mile. The criteria for designating UAs are developed by the Census Bureau and maps of UAs are published after each decennial census. The most recent UA maps reflect the results of the 2010 Census. EPA does not require coverage of municipalities outside of Urbanized Areas but allows the permitting authority (RIDEM) to designate additional MS4s outside of Urbanized Areas. Aquidneck Island's three municipalities each have regulated MS4s, by virtue of having Urbanized Areas, authorized under the MS4 General Permit (**Figure 3-1**).

The MS4 General Permit provides detail on the requirements and implementation of the six Minimum Control Measures (MCM) required under Phase II (**Table 3-1**):

- Public education and outreach,
- Public involvement and participation,
- Illicit discharge detection and elimination (IDDE),
- Construction site stormwater runoff control,
- Post-construction stormwater management in new development and redevelopment, and
- Pollution prevention and good housekeeping in municipal operations.

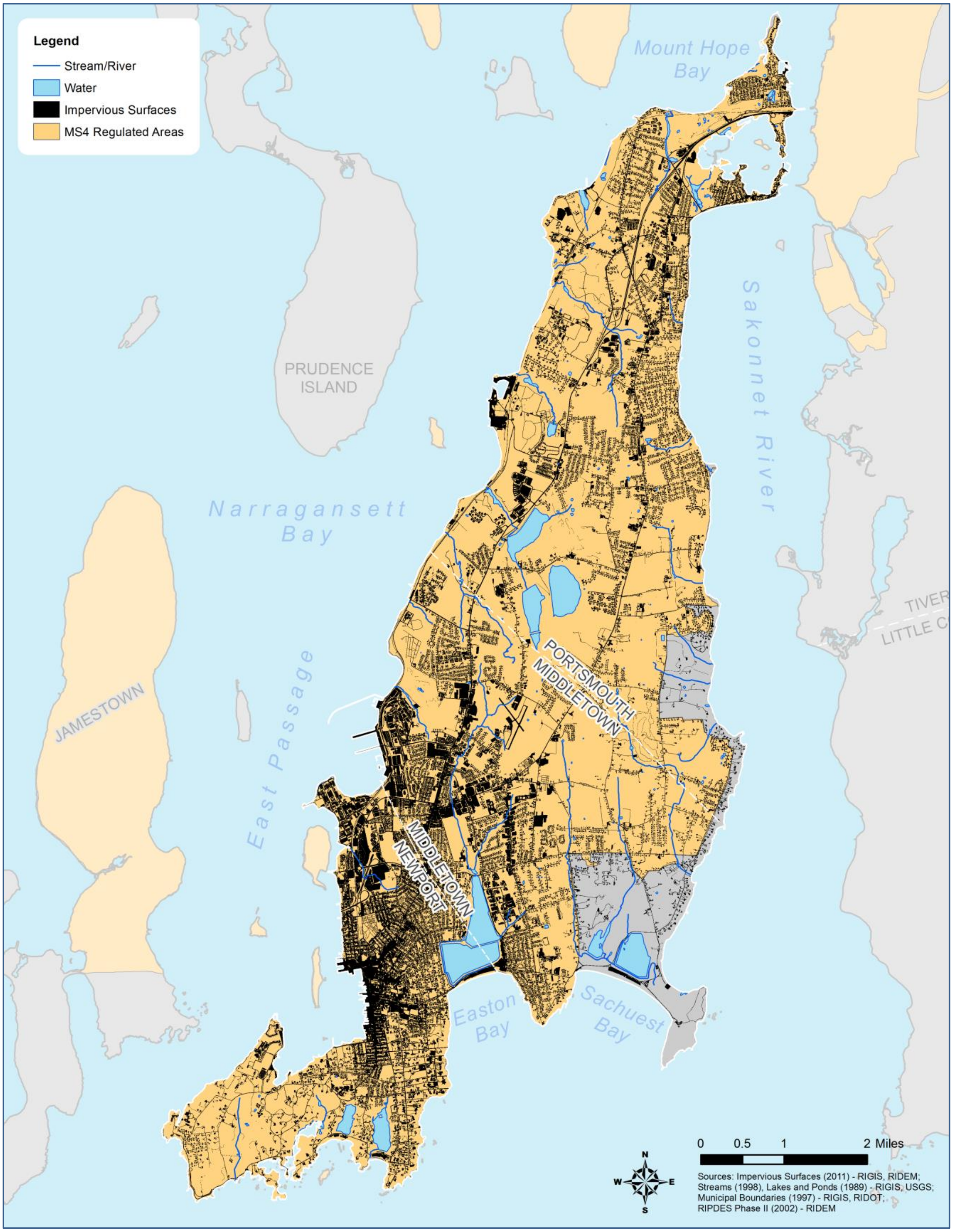

Figure 3-1. MS4 Regulated Areas

Table 3-1: Summary of Minimum Control Measures (MCMs) and Related Requirements

Minimum Control Measure	BMP Requirement	Description
MCM #1: Public Education and Outreach	• Implement ongoing public stormwater education program • Develop/acquire and disseminate educational materials • Incorporate measures for Stormwater Pollutants of Concern associated with impaired waters	• To raise awareness that polluted stormwater runoff is the most significant source of water quality problems • To motivate residents to use Best Management Practices (BMPs) which reduce polluted stormwater runoff • To reduce polluted stormwater runoff as a result of increased awareness and utilization of BMPs
MCM #2: Public Involvement/ Participation	• Provide public notice to solicit public comment for the annual reports	• Involve the community in both the planning and implementation process of improving water quality • Provide opportunities to engage the community to participate in the review of annual reports
MCM #3: Illicit Discharge Detection and Elimination	• Establish legal authority necessary to prohibit, investigate and eliminate illicit discharges • Develop a list and map of all stormwater outfalls • Develop and implement written Illicit Discharge Detection and Elimination (IDDE) Standard Operating Procedures (SOPs), including for illegal dumping • Identify priority areas to locate and remove the source of illicit discharges • Conduct dry–weather screening of MS4 outfalls for illicit discharges • Inform public employees, businesses and general public about hazards associated with illegal discharges	• Provide the legal authority to prohibit and eliminate illicit discharges to the MS4, find the source of any illicit discharges, eliminate those illicit discharges, and ensure ongoing screening and tracking to prevent and/or eliminate future illicit discharges.

Minimum Control Measure	**BMP Requirement**	**Description**
MCM #4: Construction Site Storm Water Runoff Control	• Establish legal authority requiring that applicants for development and redevelopment within the municipality use erosion and sediment control measures • Develop and implement interagency coordination procedures • Require site operators to develop and implement a Storm Water Pollution Prevention Plan and control wastes • Perform plan reviews and inspections • Incorporate public involvement into site development activities • Notify developers of RIDEM's construction general permit	• To control stormwater discharges (to its MS4) associated with land disturbance or development (including redevelopment) activities from sites (as defined in RIDEM's General Permit for Storm Water Discharge Associated with Construction Activity) with one or more acres of soil disturbance, whether considered individually or collectively as part of a larger common plan
MCM #5: Post-Construction Storm water Management in New Development and Redevelop-ment	• Establish legal authority to implement construction site stormwater runoff control using BMPs and Low Impact Development (LID) appropriate for site conditions to minimize water quality impacts • Require runoff reduction and LID measures in new development and redevelopment appropriate for the community • Develop and implement procedures for site plan review to ensure compliance with RIDEM's Stormwater Design and Installation Manual • Develop and implement a maintenance plan for ensuring the long-term effectiveness of stormwater basins and other treatment structures	• Promote the use of Low Impact Development (LID) and runoff reduction site planning and development practices in new development and redevelopment
MCM #6 - Pollution Prevention and Good House-keeping in Municipal Operations	• Identify operations with potential to introduce pollutants to a MS4 • Develop and implement program to reduce stormwater volume from MS4 operator • Employee training • MS4 property and operations maintenance • Develop and implement a program to control the contribution of pollutants to its MS4 from commercial, industrial, municipal, institutional or other facilities, not otherwise authorized by RIDEM general permits	• Prevent or reduce pollutant runoff, and protect water quality, from all municipally-owned or operated MS4s

.

The MS4 General Permit requires the filing of a Notice of Intent (NOI) to obtain permit coverage and development and implementation of a Stormwater Management Program Plan (SWMPP). The City of Newport, Town of Middletown and Town of Portsmouth originally developed Stormwater Management Program Plans and submitted a Notice of Intent to obtain individual coverage under the 2003 MS4 Permit.

3.1 City of Newport

The following information is a program summary based on the most recent annual report available for review submitted by the City of Newport in 2016. A detailed table of this information is also included in **Appendix A**.

MCM #1: Public Education and Outreach

The City of Newport has a multi-layer education and outreach program that has disseminated public education materials via the City's website. Materials include brochures with information on vehicle/garage practices, lawn/garden usage, pet care, swimming pool maintenance, and septic system use and maintenance. Additionally, the City has contracted the development of further printed stormwater informational materials to be distributed to residents, businesses, landscapers, and schools. The City has also held informational public meetings associated with several drainage studies undertaken to develop various stormwater controls.

MCM #2: Public Involvement and Participation

The City provided public notices soliciting feedback on the Stormwater Management Program Plan (SWMPP) and annual reports. In addition, there is a private citizen committee on wastewater and stormwater system improvements, which prepares semi-annual reports to the Council. The City also conducted household hazardous waste cleanup events, community and stakeholder meetings, and weekly monitoring of the Newport Harbor as well.

MCM #3: Illicit Discharge Detection and Elimination (IDDE)

The City instituted an IDDE ordinance in 2006. The City completed outfall and system mapping in 2010, incorporating this data into the municipal GIS, and regularly updates this information. The City also maintains standard operating procedures to record and investigate complaints, conduct source identification investigations and remove of illicit discharges. All catch basins and manholes have been inspected for illicit connections, and catch basins continue to be inspected annually for illicit discharges during mosquito abatement operations. Field screening and testing for dry weather flows have been completed annually since 2006. Public education materials relevant to MCM#1 also include information on the hazards of illicit discharges. No illicit discharges were detected in 2016.

MCM #4: Construction Site Storm Water Runoff Control

The City has an ordinance relating to sediment and erosion control at construction sites that was adopted in 2007. Public meetings are held for all significant projects and comments are received and addressed. Four construction applications were received and reviewed in 2016.

Four active construction projects received 6 site inspections in 2016 leading to one (1) violation being issued and corrective action taken.

MCM #5: Post-Construction Storm water Management in New Development and Redevelopment

The City passed a Post-construction Runoff from New Development and Redevelopment ordinance in 2008. The City requires the use of Best Management Practices (BMP) Operation and and Maintenance (O&M) agreements, which specify the party responsible for long-term O&M and a description and location of the BMP; and they are tracked via a GIS database. There were no applications received for eligible BMPs in 2016.

MCM #6: Pollution Prevention and Good Housekeeping in Municipal Operations

The City inspects all catch basins (2,660) annually during mosquito abatement operations. Additionally, the City cleaned nearly 1,300 of these structures in 2016. The City continues to sweep all City-owned streets at least once annually. The City maintains an inventory of MS4-owned BMPs and maintains these structures on an annual basis. Finally, the City conducts annual training on relevant Stormwater Pollution Prevention Plan (SWPPP) or Spill Prevention, Control and Countermeasure (SPCC) procedures depending on their position and responsibilities.

3.2 Town of Middletown

The following information is a program summary based on the most recent annual report available for review submitted by the Town of Middletown in 2016. A detailed table of this information is also included in **Appendix A.**

MCM #1: Public Education and Outreach

The Town disseminates public education materials via the Town's website, and provides brochures with information on IDDE, fertilizer use, and septic system use and maintenance to residents at Town Hall, public libraries, and by mail. In July 2016, the Town distributed a flier describing best practices for use and disposal of automotive fluids, fertilizers and pesticides, pet and human waste, detergent, debris and litter to residents. Information on pump-out locations and the pump-out boat is provided seasonally to mooring lessees by the Harbor Master to better inform recreational boaters on wastewater treatment options.

MCM #2: Public Involvement and Participation

The Town has provided all required public notices soliciting feedback on the SWMPP and annual reports. The Town has also conducted public meetings on stormwater issues and offers opportunities for residents to be involved at Roads and Utilities Committee meetings. Finally, the Town encourages resident participation in various cleanup events.

MCM #3: Illicit Discharge Detection and Elimination (IDDE)

The Town adopted an IDDE ordinance in 2006. Outfall and system mapping was completed in 2009 and information is regularly updated in GIS. The municipal SWMPP also describes operating procedures to record and investigate complaints and tracing and removing illicit discharges. All catch basins and manholes were inspected for illicit connections in 2007. Field screening and testing for dry weather flows was completed in 2009. The Town coordinates with the City of Newport, RIDEM, RIDOH, and the Rhode Island Coastal Resources Management Council (CRMC) to address stormwater issues around Easton's Beach. Public education materials relevant to MCM#1 also include information on the hazards of illicit discharges.

MCM #4: Construction Site Storm Water Runoff Control

The Town passed an ordinance relating to sediment and erosion control at construction sites in 2006. The Town Building Official handles complaints and, along with the Town Engineer and Department of Public Works (DPW) Director, implements policies and procedures for all construction projects. Seventeen (17) construction applications were received and reviewed in 2016. Twenty-six (26) active construction projects received thirty (30) site inspections in 2016, resulting in zero (0) violations.

MCM #5: Post-Construction Storm Water Management in New Development and Redevelopment

The Town has a Post-construction Runoff from New Development and Redevelopment ordinance that was adopted in 2006 that also ensures long-term Operation and Maintenance (O&M) of BMPs. Thirteen (13) of seventeen (17) active construction projects were completed and inspected for proper installation in 2016.

MCM #6: Pollution Prevention and Good Housekeeping in Municipal Operations

The Town maintains an inventory of MS4-owned BMPs and inspects and maintains them on an annual basis. Street sweeping is conducted by the Town at least once a year. Middletown also inspects all catch basins annually and cleans and maintains the catch basins and culverts as necessary. Finally, the Town provides relevant training to municipal employees annually and recently trained all DPW employees on the elimination of the winter-time application of road sand in 2016.

3.3 Town of Portsmouth

The following information is a program summary based on the most recent annual report available for review submitted by the Town of Portsmouth in 2011. A detailed table of this information is also included in **Appendix A.**

MCM #1: Public Education and Outreach

Portsmouth maintains public education materials on the Town website. The content on the website includes a variety of information on stormwater, along with a list of activities and best practices for minimizing residents' water quality impacts.

MCM #2: Public Involvement and Participation Portsmouth provided public notices soliciting feedback on the SWMPP and annual reports.

MCM #3: Illicit Discharge Detection and Elimination (IDDE)

The Town passed an IDDE ordinance in 2008 and completed outfall and partial system mapping in digital format in a GIS in 2008. All catch basins and manholes were inspected for illicit connections, along with field screening and testing for dry weather flows was completed in 2007. Since the beginning of the program, five (5) illicit discharges have been identified and three (3) have been eliminated. The IDDE program in Portsmouth is still ongoing and new information is being gathered in the neighborhoods of Portsmouth Park and Island Park.

MCM #4: Construction site Storm Water Runoff Control

Portsmouth has an ordinance relating to sediment and erosion control at construction sites that was originally passed in 1993 and updated in 2010. The Town Building Official handles complaints and reviews and inspects all construction projects. The posting of a bond prior to issuance of a building permit, which is released with a certificate of occupancy, is required.

MCM #5: Post-Construction Storm water Management in New Development and Redevelopment

The Town continues to work on adopting a Post Construction Runoff ordinance, however procedures are in place for the review and inspection of new and redevelopment sites. There was one (1) application received and reviewed for eligible BMPs in 2011. In that same year, one (1) complaint of a malfunctioning structural BMP was received and investigated and remedial action was underway. Fifteen (15) site inspections of structural BMPs were also conducted in 2011.

MCM #6: Pollution Prevention and Good Housekeeping in Municipal Operations

According to the 2011 Annual Report, Portsmouth keeps an inventory of MS4-owned BMPs which are inspected and maintained them by the Town. Other activities included street sweeping at least once a year, inspection and cleaning of catch basins and manholes, and informal training to municipal employees.

3.4 Potential Future MS4 Requirements

The RI MS4 permit was initially authorized with a five year term but has subsequently been renewed, unchanged, on a year to year basis. As such, there are no “new” requirements under the RI MS4 permit; towns need only comply with the original permit issued in 2003.

As of September 2017, there is no expectation that the status of the MS4 program will change in the short term (1-2 years). However, recent updates to the MS4 permits in the neighboring states of Connecticut and Massachusetts suggest that an update to these regulations is possible in the future.

While it is impossible to know exactly what might be required under a new Rhode Island MS4 general permit, it is reasonable to look at these recent permit updates in Connecticut and Massachusetts for information on what future requirements may be. It should also be noted that since the Commonwealth of Massachusetts does not have the delegated authority from

EPA to implement the permit, the MS4 permit in Massachusetts, which is administered by EPA, is a direct indication of what EPA views as important inclusions to the permit. Below is a breakdown of each Minimum Control Measure and the possible updates that could become part of a future RI MS4 general permit.

MCM #1: Public Education and Outreach

Outside of the requirement to document how the municipality will go about educating and coordinating with the public, there is little additional action that towns are required to take under the current regulation. They currently have latitude on the types of messaging, the audience they want to target, and the media used to disseminate that message. The new Connecticut and Massachusetts permits have more specific requirements which include a specific number of messages that need to be targeted to specific audiences. For example, in MA, regulated MS4s are required to disseminate two (2) messages to four separate "audiences" within the permit term. The audiences are Residential, Commercial, Developers and Industrial. Therefore, it is possible that a future RI MS4 general permit may also incorporate more specific requirements.

MCM #2: Public Involvement/Participation

Major changes to this MCM are not anticipated. If additional requirements were instituted, they would likely include more specific requirements related to public notices. These could include a more specific process by which towns are to notify the public about the status of their Stormwater Management Program Plan or Annual Report, or more specific language detailing where notices can or cannot be posted (i.e. website, newspaper, Town Hall, etc.).

MCM #3: Illicit Discharge Detection and Elimination (IDDE)

This MCM had some of the most significant changes when comparing the new Connecticut and Massachusetts permits with their previous iterations. This would suggest that any new permit issued in Rhode Island would see similar alterations to the requirements of this MCM. Additional requirements might include more specific mapping, additional dry and wet weather screening of outfalls, new requirements for catchment investigations, and inventories and logs for Sanitary Sewer Overflows (SSOs). While the Rhode Island permit already has more specific and stringent dry-weather outfall monitoring than the previous Connecticut and Massachusetts permits, additional mapping requirements (locations for catch basins, manholes, pipes, etc.) and catchment investigation requirements could be a part of any new Rhode Island permit.

MCM #4: Construction Site Stormwater Runoff

Largely unchanged from the initial MS4 permits in Massachusetts and Connecticut, this MCM could see additional requirements requiring updates to local regulations or ordinances. There could also be new requirements for specific, written procedures for site review and inspection, as well as documentation requirements for corrective actions needed.

MCM #5: Post-Construction Stormwater Management in New Development and Redevelopment

This MCM could see upgraded requirements specific to the design guidance for post-construction features. For example, the permit could require that development/redevelopment sites meet specific removal standards for various pollutants or treat a specific volume of stormwater in order to be compliant. In Connecticut, permittees are also required to calculate, track, and disconnect where possible 2% of their Directly Connected Impervious Area (DCIA) by year five (5) of the permit. The calculation, tracking and removal of DCIA could also be included in a future Rhode Island permit.

MCM #6: Pollution Prevention/Good Housekeeping

Similar to MCM #3 this MCM is likely to have additional and more specific requirements. Changes that have occurred in the Connecticut and Massachusetts permits include specific timelines for catch basin inspection, cleaning, more stringent record keeping, more specific requirements related to street sweeping, and more specific and written SOPs related to snow and ice practices (i.e., tracking the number of lane miles treated, amount of deicing agent used, and type of deicing agent). In addition to these more programmatic inclusions, there could also be additional record keeping requirements related to other stormwater related infrastructure including the age of various system components (manholes, pipe, catch basins, etc.), specific data collection requirements for catch basin or manhole inspections, or even asset management requirements relative to the stormwater system.

TMDL Requirements

The Rhode Island MS4 permit already has requirements for discharges to waters identified by RIDEM as “impaired” and waters subject to a Total Maximum Daily Load (TMDL). However, the specific requirements could be updated or increased. Any changes to TMDL requirements could be implemented within the framework of the six Minimum Control Measures. Additional measures could include new requirements for pollutant removal within catchments discharging to an impaired segment. Additional messaging specific to the pollutants of concern could be required to be included in a municipality’s education and outreach program under MCM #1. There could also be requirements for additional street sweeping and catch basin cleaning under MCM #6.

Table 3-2: Summary of Potential Future MS4 MCM Requirements

Minimum Control Measure	**Potential Requirements**
MCM #1: Public Education and Outreach	• Specific number of messages needed to be disseminated • Required audiences where messaging will need to target (Residential, Industrial, Developers, Commercial) • More prescriptive distribution timeline
MCM #2: Public Involvement/Participation	• More or less restrictive ways to publish notice of updates to the SWMP or Annual Report • More specific or restrictive timelines for public notifications
MCM #3: Illicit Discharge Detection and Elimination	• More specific dry weather investigation requirements for outfalls and catchments • Possible wet-weather screening sampling requirements for outfalls or catchments or both • Additional mapping requirements
MCM #4: Construction Site Stormwater Runoff Control	• Possible additions to municipal ordinances or regulations • Written procedures for site inspections
MCM #5: Post-Construction Stormwater Management in New Development and Redevelopment	• Specific post-construction design guidance (e.g., Remove 90% of the average annual post-construction load of TSS) • Calculation, tracking, and removal of Directly Connected Impervious Area (DCIA)
MCM #6: Pollution Prevention/Good Housekeeping	• Increased frequency of street sweeping • Require catch basin inspection and cleaning logs • Information on disposal and/or use of street sweepings/catch basin cleanings • Mandatory Stormwater Pollution Prevention Plans (SWPPPs) for municipal facilities such as DPW yards, Highway Garages, and/or transfer stations
TMDL Requirements • Additional measures for specific MCMs	• MCM #1: Additional messaging specific to pollutants of concern • MCM #3: Additional screening/sampling requirements in wet or dry weather • MCM #6: Additional sweeping requirements for streets/parking lots

4 Recent Watershed Studies

Several recent watershed studies on Aquidneck Island have detailed the need for additional actions to reduce stormwater and agricultural runoff, and developed specific recommendations for mitigation measures (water quality best management practices, or BMPs) to prevent or reduce pollutant loading to the Island's waters. Recommendations include both structural BMPs (constructed systems such as stormwater basins, designed to increase stormwater infiltration into the soil) (**Figure 4-1**) and non-structural BMPs (measures to change human behavior or improve land management practices to reduce pollution). On Aquidneck Island, soils with poor ability to infiltrate rainfall/runoff and high groundwater limit design options for structural BMPs, since BMPs that reply on infiltration are not as effective in this type of setting. **Table 4-1** below provides a brief description of previous recent studies that have made recommendations about BMP options on Aquidneck Island. As part of the **Island Waters** project, potential BMPs in the Sisson Pond and Lawton Valley Reservoir watersheds were also defined at a conceptual level and are described in this report. Prior to this, no specific BMPs had been identified in these watersheds. In addition, other individual BMPs have been identified for the Island based on the input from stakeholders in the **Island Waters** project (**Section 4.5**). Note that in cases where the previously recommended BMPs have already been or are under construction, they are not included in the maps and tables in the descriptions of BMPs in this section or **Appendix B**.

Table 4-1. Summary of Prior Studies Identifying BMPs

Study	Description
Newport Source Water Phosphorus Reduction Feasibility Study (2016)	Study estimated nitrogen and phosphorus loading sources in the St. Mary's Pond Watershed and within the pond, and identified structural and non-structural BMPs for nutrient reduction from the watershed.
Maidford River Watershed Assessment & BMP Design (2016)	Study examined flooding and water quality problems in the Maidford River Watershed, and recommended structural and non-structural BMPs to address these issues.
Maidford River and Paradise Brook Watershed Conservation Plan (2017)	Plan identified target parcels for the Aquidneck Land Trust to conserve with the aim of installing structural BMPs to mitigate flood risk on the Maidford River and Paradise Brook.
North Easton (Green End) Pond Stormwater Attenuation and Source Reduction Strategy (2013)	Plan identified a set of structural BMPs to reduce bacteria and phosphorous loadings to Bailey's Brook and North and South Easton Ponds. BMP locations were mostly focused within existing rights-of-way (ROWs).

Table 4-2 provides a brief description of the types of structural BMP that have been identified to date, as well as their effectiveness for pollutant removal and general relative cost. In addition, **Table 4-3** provides additional information on non-structural BMPs, which focus on nutrient and bacteria source reduction through behavioral change and provide an important complement to the design and implementation of structural BMPs.

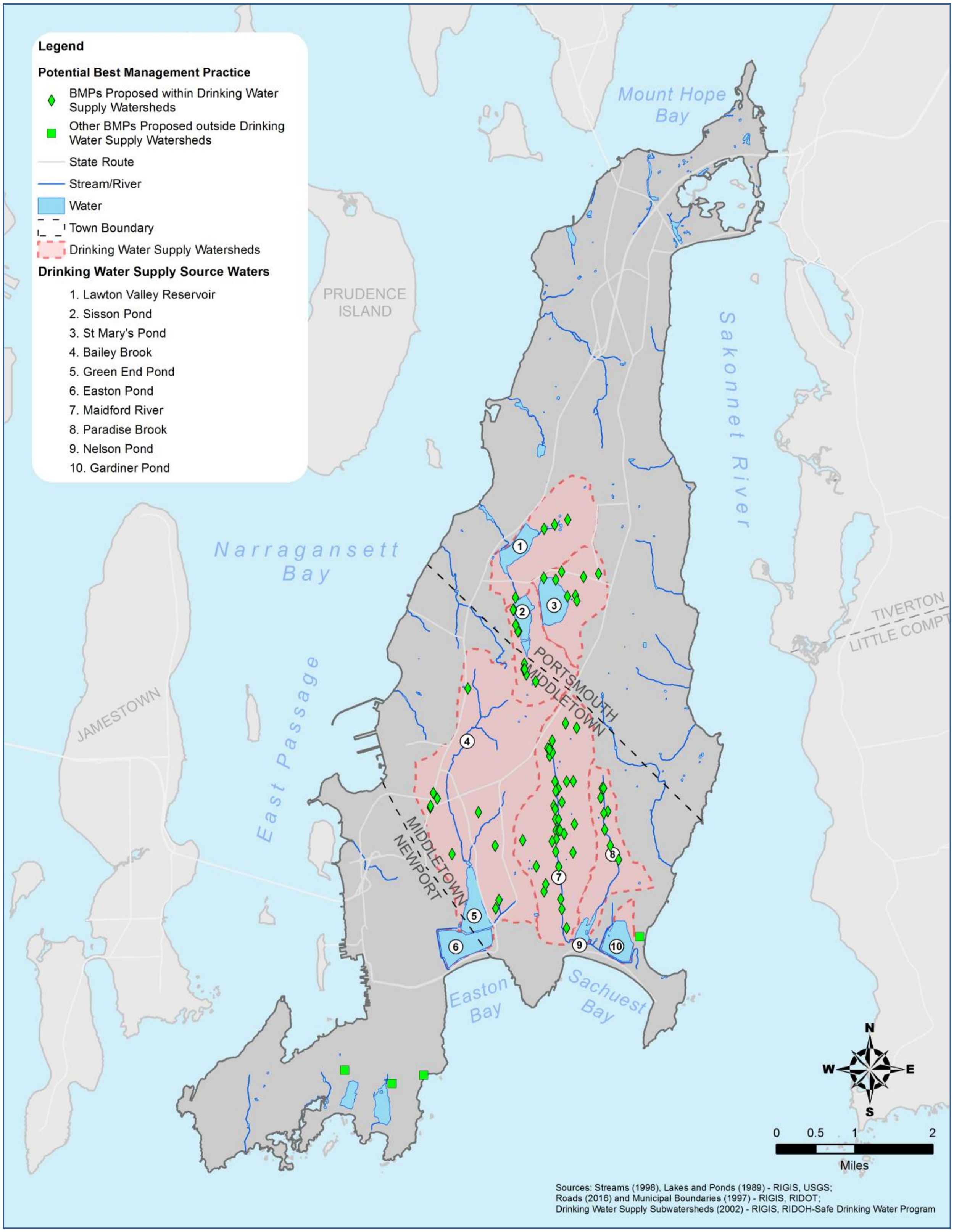

Figure 4-1. Location of Potential Structural BMPs

Table 4-2. Structural Best Management Practices

Type	Description	Water Quality Benefits				Opportunities	Limitations	Cost	Maintenace
		TP	TN	TSS	Bacteria				
Infiltration/Filtering Practices	Infiltration practices store the water quality volume (WQV) in the void spaces of a trench or open chamber before it is infiltrated into underlying soils. Filtering practices treat stormwater by settling out larger particles in a sediment chamber, and then filtering stormwater through a surface or underground media matrix.	●●●	●●	●●	●●●	Best opportunities for infiltration systems are in well-draining soils that can manage a significant hydraulic load. Infiltration practices are very efficient in addressing bacteria and other sediment-bound pollutants such as phosphorous. These systems also reduce volumes of water and can help minimize drainage and flooding issues. Filtration practices are not dependent on hydraulic capacity of underlying soils but still will provide similar pollutant reduction as infiltration but no stormwater volume reduction.	Infiltration practices are ideally located in areas with highly permeable soils (infiltration rates of >0.5 in/hr). Typically requires separation from seasonally high ground water. Ideally not placed under pavement or concrete for easier maintenance.	$$	
Wet Vegetated Treatment Systems (WVTS)	A surface wet stormwater basin that provides water quality treatment primarily in a shallow vegetated permanent pool. A wet stormwater basin that provides water quality treatment primarily in a wet gravel bed with emergent vegetation.	●●●	●●●	●●	●●●	Funding opportunities may exist through the Section 319 Grant program, as well as other local grant programs that target stormwater BMPs. Wetland systems can provide both aquatic and terrestrial habitat improvements.	Requires contributing drainage areas of 5-10 acres. Substrate needs to be maintained in a saturated condition which means this practice is best in areas with a high water table and a shallow depth to groundwater. Due to sizing requirements, this practice typically requires a larger amount of available space than other practices which could restrict siting.	$$$	
Linear Bioretention	Linear bioretention, or open channel systems, are vegetated open channels that are explicitly designed to capture and treat the full WQV within dry or wet cells	●●●	●●●	●●	●●	Linear bioretention systems are best located along roads within the ROW where adequate space exists between the edge of pavement and ROW. These practices are best suited where slopes are	Grass species selected for Dry Swales need to be appropriate for the environmental setting and be able to withstand high velocities at times along with	$	

Type	Description	Water Quality Benefits				Opportunities	Limitations	Cost	Maintenace
		TP	TN	TSS	Bacteria				
	formed by check dams or other means. These include both Dry and Wet Swales.					minimal. Existing roadside ditches that exist in Middletown and Portsmouth can often be retrofitted into a linear bioretention system.	inundation. Little habitat benefit unless the channel is designed as a Wet Swale Wet Swales provide more phosphorus removal than Dry Swales.		
Bioreactor	Bioreactors consist of a trench filled with wood chips or other carbon source that are constructed to intercept the shallow groundwater table. This carbon source and the presence of nitrogen in groundwater create conditions which allow bacteria to convert dissolved nitrogen to nitrogen gas.	●	●●●	●	●	The best opportunity for bioreactors is to reduce elevated levels of nitrogen in groundwater. These systems would be located on the downgradient edge of a site with elevated levels of nitrogen such as an agricultural field.	Limited to primarily treating nitrogen in groundwater.	$	
Tree Filter	Tree filters have a number of design configurations but can generally consist of a tree well into which curbside runoff is directed. The tree and the media that it is planted serve to both filter and uptake pollutants such as nutrients and bacteria.	●●●	●	●●	●●●	Tree filters are best located in urbanized or developed landscapes where other BMPs may not fit. Also can be an opportunity where tree canopy is limited and significant impervious coverage.	While an individual tree filter is inexpensive, they manage only small volumes of runoff	$$$	
Filter Berm	Filter berms consist of a stable, permeable berm such as gravel or compost, placed at the downgradient edge of an agricultural field. The filter media in the berm serves to both filter the runoff from the fields and provide some opportunity for cation exchange of dissolved pollutants.	●●●	●	●●●	●●●	Best opportunity for filter berms are along the downgradient edge of agricultural fields or other non-point sources that have space where water can be stored behind the berm. These would be locations with fields where there is significant potential for sediments and nutrients.	Requires adequate space to store runoff upstream of the filter berm where water will pond during a storm event before it filters through the berm.	$	

Table 4-3. Non-Structural Best Management Practices

Type	Description	Water Quality Benefits			Opportunities	Limitations	Cost
		Nutrients	Sediment	Bacteria			
Riparian Buffer 	A riparian buffer is a vegetated area adjacent to a water body, usually forested, which helps shade and partially protect it from the potential impacts of adjacent land uses. It plays a key role in reducing the negative effects of stormwater and can help to improve water quality in associated streams, rivers, and lakes.	●●●	●●●	●●●	Riparian buffers, regardless of width, can provide excellent habitant enhancement benefits for multiple species of plants, insects and animals. There are several opportunities where enhanced riparian buffers would improve water quality draining overland directly to impaired waters. These are locations where agricultural operations or lawns have extended to the edge of a water supply or stream draining directly into a water supply. Funding and technical support for riparian buffers is available through the Natural Resource Conservation Service (NRCS) Environmental Quality Incentives Program (EQIP)	May require land acquisition which can be expensive. Buffer efficiency is directly tied to buffer width for both nutrient and sediment removal efficiency. Sweeney and Newbold (2014) suggest buffers be >30m in width to protect physical, chemical and biological integrity of small streams.	$$$
Nutrient Management (fertilizer, manure, irrigation) 	Nutrient Management programs aim to manage the amount, source, placement and timing of fertilizers, manure, and soil amendments to agricultural landscapes in order to minimize cost and protect natural resources.	●●●	●●	●	Nutrient management is a critical element in watersheds where agricultural operations are contributing excess nutrients that are causing a water quality impairment. The success of these programs is often driven by participation in existing federal funding and technical support through: -NRCS EQIP Program -RCPP-regional Conservation Partnership Program -NRCS Agricultural Management Assistance Program (AMA)	Requires "buy-in" from property owner(s) to be effective. A proper Nutrient Management Plan typically involves soil testing which can increase overall cost.	$$$

Type	Description	Water Quality Benefits			Opportunities	Limitations	Cost
		Nutrients	Sediment	Bacteria			
Street Sweeping 	Street sweeping is a BMP that has been implemented for some time as a requirement of NPDES programs. There have been some more recent studies suggesting that more frequent sweeping and the type of equipment used to complete the sweeping can have additional positive effects while offering a cost-effective means to improve stormwater quality.	●●	●●●	●●	Can improve neighborhood aesthetics. Target more frequent sweeping (and catch basin cleaning) in areas of heavier sediment accumulation. Municipal DPWs would best be able to identify locations where increased street sweeping could be beneficial.	Increasing the frequency of sweeping will have obvious impacts on overall program cost. The type of sweeper has shown to have an effect on overall removal efficiency. Vacuum-assisted and regenerative air sweepers have been found to be more effective. These sweepers are not as common as mechanical sweepers and are typically more costly.	$$
Residential Education (Lawn Care,  Pet Waste Management, Septic Maintenance)	Residential educational programs can be extremely cost effective mechanisms to reach out and help change behaviors that have a negative impact on water quality. Programs can have several messages but the most common typically involve pet waste management, septic system maintenance and lawn/turf management.	●●●	●	●●●	Can be very effective where neighborhood practices are having significant water quality impacts where a public education campaign can voluntarily change behaviors resulting in an effective long-term and cost effective reduction in stormwater pollutants. Examples can include fertilizer and pet waste management. Lawn care and fertilizer applications should be a priority for public education on Aquidneck Island.	Hard to quantify any improvements due solely to a pet waste management program. Requires public buy-in to be effective. Can require frequent maintenance (i.e., waste disposal, refreshing waste bag stations).	$

Key	Water Quality Benefits	Construction Cost	Maintenance Requirements
High	●●●	$$$	
Medium	●●	$$	
Low	●	$	

4.1 Maidford River and Paradise Brook

Two studies have recently examined opportunities for water quality best management and conservation practices in the Maidford River and Paradise Brook watersheds (Fuss & O'Neill, 2016; 2017). These studies were funded by a US Department of Interior National Fish and Wildlife Foundation Hurricane Sandy Coastal Resiliency Grant to the Town of Middletown.

The first study, *Maidford River Watershed Assessment & BMP Design* (Fuss & O'Neill, 2016), examined water quality data from RIDEM collected during both wet and dry weather and used a land use-based pollutant loading model to identify pollutant sources in the watershed. The RIDEM monitoring demonstrated the impact of stormwater on the streams since significant wet weather increases in total phosphorus and bacteria concentrations were observed in the streams. Increasing fecal coliform bacteria concentrations moving downstream in the Maidford River watershed point away from on-site sewage disposal systems as a bacteria source (the southern half of the watershed is sewered) and suggest the influence of livestock, wildlife, and residential land use driving bacteria generation, and attachment to sediment as a mode of bacteria transport due to high sediment loads. These observations are consistent with the TMDLs (RIDEM, 2011a,b,c) for the watersheds. Pollutant load modeling conducted as part of the study found that throughout the entire watershed nursery/cropland and residential areas generate the highest nutrients and sediment loads, a result which is also consistent with RIDEM's recent observation of higher instream turbidity concentrations near agricultural areas within the watershed (RIDEM, 2017). Residential areas are main source of bacteria, with medium density residential generating 64% of the modeled annual load according the study. These pollutants are transported to the streams and to drinking water supply reservoirs via stormwater.

Poor natural soil infiltration, watershed development, undersized culverts, and stream channelization increase flood risk in the watershed. These conditions restrict the effectiveness of some BMPs, requiring thoughtful selection of structural BMPs that would provide pollutant attenuation given the limited potential for infiltration due to the predominance of soils with poor infiltration capacity. Recommended BMPs (**Appendix B**) include retrofit of existing swales, bioretention, and tree filters which are anticipated to perform well within the watershed conditions. The report also recommends BMPs to decrease flood frequency and severity and pollutant discharge, including floodplain restoration. Non-structural agricultural BMPs depend on the context of individual agricultural operations, but include BMPs recommended by USDA's Environmental Quality Incentives Program (EQIP) such as residue and tillage management, nutrient management, riparian forest buffers, streambank and shoreline protection, etc. Other BMPs recommended include streambank repair, homeowner lawn care education, on-site wastewater treatment system (OWTS) maintenance, pet waste program enforcement, and hobby farm fertilizer use and manure management.

The second study, *Maidford River and Paradise Brook Watershed Conservation Plan*, was prepared for the Aquidneck Land Trust (ALT). It builds on the results of the first study to prioritize parcels within the watershed that ALT might target for conservation through the purchase of development rights, a conservation easement, or fee simple acquisition. Fuss & O'Neill conducted stream walks along each stream to determine pollutant sources and potential restoration projects within the riparian corridor.

Field assessment of the stream corridors confirmed that pollutant loading in both the Maidford River and Paradise Brook watersheds is significantly affected by agriculture, although residential land use is estimated as the major source of bacteria. The study also emphasizes that the Maidford River experiences flooding, with a number of the roads in the watershed experiencing regular overtopping.

The stream walks found impacted buffers, agricultural operations, and stormwater and erosion impacts along the two streams. The study reported that impacted riparian buffers are predominately located in headwater areas of the watersheds, where primary land uses are cropland and pasture. Stormwater impacts were found to be present throughout the watershed and contributing to the sediment load in the streams.

The Plan describes BMPs for floodplain restoration by increasing riparian buffer along the Maidford River from Wyatt Road to Green End Avenue, installing bioreactors and filter berms downslope of agricultural fields at the headwater of the Maidford River (**Appendix B**), and various combinations of these BMPs along the Paradise River (**Appendix B**). It further sets out an implementation plan to turn proposed activities into realized conservation actions. Finally, the plan outlines BMPs for an outreach and advocacy approach customized to the various stakeholders who would likely be involved in land or easement transactions and generally over the life of the Plan. Several of the BMPs originally recommended by these plans were constructed in Spring 2017: retrofitting the existing detention basin at Hoogendoorn Farm, and pairs of bioretention basins at the intersection of Green End Avenue and Berkeley Avenue and at Paradise Valley Park.

4.2 St. Mary's Pond

The *Source Water Phosphorus Reduction Feasibility Plan* (Fuss & O'Neill, 2016), prepared for the City of Newport Water Division, examined ways to reduce nutrient inputs to St. Mary's Pond on Aquidneck Island and another water supply reservoir located off the island. This project was funded by an agreement awarded by the U.S. Environmental Protection Agency to the New England Interstate Water Pollution Control Commission in partnership with the Narragansett Bay Estuary Program.

This study assessed in-lake and watershed sources of phosphorus and recommended structural and non-structural BMPs for the reduction of phosphorus loading. The structural BMPs focused on retrofits to existing stormwater management structures, as well as new structures in existing rights-of-way (ROWs) and opportunities for buffer restoration with the City of Newport's land immediately surrounding the water bodies. St. Mary's was chosen for the study based on a history of harmful algal bloom formation indicated by water quality data collected by Fuss & O'Neill (2011-2012, 2015) and RIDEM (2011-2012, 2014, and 2015).

Water quality data indicated consistently elevated levels of total phosphorus typical of mesotrophic and eutrophic water bodies, capable of supporting algal blooms. Estimates of watershed loading of nutrients were based on output of the Watershed Treatment Model, which showed approximately 74% of the overall annual phosphorus loading to St. Mary's Pond originating in the watershed. Surrounding land uses that contribute significantly to this loading are residential development followed by developed recreation (e.g. golf courses, athletic fields).

The study recommended a suite of BMPs best suited for the particular activities and physical conditions present in the watershed that focused on the use of bioretention systems, WVTS, and tree filters or filtration systems, some of which would be retrofits to existing stormwater infrastructure. Again, these are BMP types that are expected to perform well give the pollutants of concern and soil conditions in the area. Buffer restoration was also recommended in areas where the vegetated buffer had been reduced to grass along St. Mary's Pond. More detailed information on the individual BMPs is included in **Appendix B**.

4.3 North Easton Pond

The *North Easton Pond Stormwater Attenuation and Source Reduction Strategy* report prepared for the Town of Middletown by Fuss & O'Neill in 2013 identified potential structural and non-structural BMPs to reduce phosphorus and bacteria loading to North Easton Pond. It delineated catchments and calculates the impervious cover percentage and hydrologic soil group within each, in order to recommend a suite of BMPs.

The report described the design of BMPs, advantages and disadvantages of each, and made recommendations based on their appropriateness for the groundwater depths and soils in Middletown. These recommendations included:

- Bioretention cells which fit well into ROWs: associated media and vegetation filter bacteria and provide nutrient uptake, while providing some aesthetic value.
- Wet vegetated treatment systems (WTVS), which are less aesthetically pleasing, but treat a large volume of water in a relatively small footprint.
- Sand filters that do not include a vegetated treatment component and may require more intensive maintenance than the other two.

The structural BMPs recommended as part of this report were reviewed as part of the current **Island Waters** project in order to identify those BMPs that would be most feasible to be implemented. This subset of BMPs (**Appendix B**) focuses on bioretention basins located within the Town-owned roadway ROW. These basins have significant potential to reduce nutrient and bacteria loadings to Bailey's Brook and North Easton Pond. Since they are also located in the ROW, property ownership will not be an issue for construction.

Several bioretention BMPs are currently being designed in the ROW for the Aquidneck Corporate Park that were originally proposed as part of plan for North Easton Pond. These BMPs are expected to be constructed later this year through funding by the Town of Middletown and the Narragansett Bay and Watershed Restoration Fund and are not included in **Appendix B**.

The second part of the report discussed potential for phosphorus source reduction by conducting a survey within each catchment of phosphorus and bacteria sources, such as farms, and lawn maintenance. Based on these observations, the report recommended non-structural BMPs like semiannual street sweeping in sensitive areas with priority given to catchments with sources of both phosphorus and bacteria. The report also noted the Town's awareness and outreach programs and enforceable policy to reduce fertilizer and yard debris.

4.4 Sisson Pond & Lawton Valley Reservoir

As part of the **Island Waters** project, the Sisson Pond and Lawton Valley Reservoir watersheds were evaluated for potential locations for placement of stormwater management practices. As in the watersheds discussed in previous sections, soils and depth to groundwater limited the options for best management practices. Bioretention, WVTS, filter berms and buffer restoration and improvements were identified as potentially feasible and effective BMPs to address water quality concerns resulting from stormwater, given the pollutants of concern and the underlying soil conditions in the area. More detailed information including maps and a list of BMPs is included in **Appendix B**.

4.5 Coastal and Other Best Management Practices

In addition to the BMPs identified in the studies discussed in Sections 4.2 through 4.4, individual BMPs have been identified by others at several locations on Aquidneck Island. These are discrete projects, each focused on a specific location rather than a watershed.

Cliff Walk, Marine Avenue, Newport

A conceptual design has been prepared for a new bioretention system below the intersection of Wetmore Avenue (paved road) and Marine Avenue (gravel road) in Newport in an open area along the Cliff Walk (**Figure 4-2**). This conceptual design calls for diverting runoff from the intersection of these two roads into a bioretention system that includes three cells. Water would drain through the cells in series, with shallow weirs separating each cell. The outlet at the bottom cell would consist of a level spreader that would drain water that exceeds the system's capacity across the Cliff Walk to the ocean. The system is not proposed to be underdrained and has a capacity to store 400 cubic feet of runoff. An estimate of $50,000 for the construction of this BMP has been prepared by others. This project will require approval from the Rhode Island Coastal Resources Management Council (CRMC) in the form of an Assent, which is necessary for any new construction project in CRMC's area of jurisdiction.

An advantage of this site is the opportunity for public education given the number of people that walk past this site each year on the Cliff Walk. This site would be a good location for incorporating public information displays explaining the value of these systems.

Figure 4-2. Catchment Area for Proposed Bioretention Area Near the Cliff Walk

Rogers High School, Newport

Preliminary planning is being completed to remove pavement and replace it with a rain garden and memorial garden on Rogers High School in Newport (**Figure 4-3**). A brick walk way is also proposed between the two buildings. An estimate of $32,400 has been provided to complete this project. This project should not require any permitting from RIDEM. It also is an opportunity to enhance public education on water quality and natural systems by providing teachers at the school with a teaching resource.

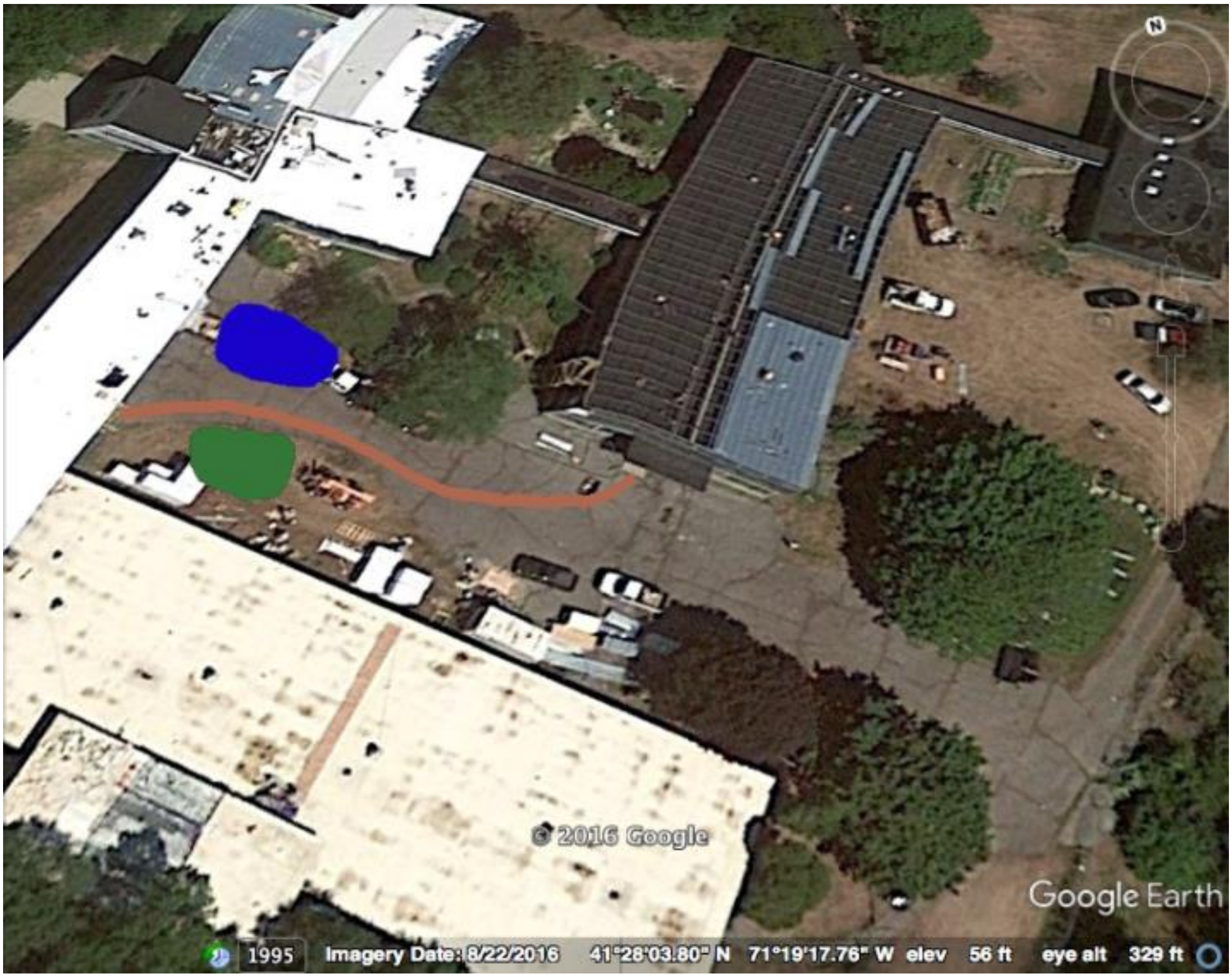

Figure 4-3. Proposed Area of Pavement Removal and Garden and Walkway Construction

Hoogendoorn Nurseries Inc., Middletown

Hoogendoorn Nurseries operates a large-scale container plant operation within the Maidford River watershed. This nursery is located on a hillside to the west of Berkeley Avenue. Runoff from this agricultural operation drains onto Berkeley Avenue, often causing drainage problems on this public road, before draining into the Maidford River. Site topography combined with lack of vegetative cover over most of this site and poorly-drained soils result in both substantial runoff volumes and sediment loadings draining from this site. Previous water quality sampling by RIDEM has found elevated levels of total suspended solids, nutrients and bacteria associated with stormwater runoff from this site during wet weather events.

The Town has recently upgraded a town-owned detention basin on a field that it leases to Hoogendoorn in order to improve the basin's hydraulic capacity as well as improve its ability to settle sediments from a portion of this property. While this basin was constructed to the maximum size practical for this location, it is still undersized to manage all of the runoff draining from the Hoogendoorn site.

The United States Department of Agriculture Natural Resources Conservation Service (NRCS) provides farmers such as Hoogendoorn Nurseries with both technical and financial assistance to protect natural resources, including water quality. As part of this program, NRCS has prepared a Conservation Plan to implement a range of practices to reduce water quality impacts from this site.

In general, this Conservation Plan proposes a number of features to be constructed to protect water quality, including:

- Access control consisting of fencing to exclude people and vehicles to protect natural resources.
- Access roads to reduce erosion along existing access roads and promote proper drainage.
- Conservation cover to establish perennial vegetative cover on land temporarily removed from agricultural production.
- Diversions to break up concentration of water on long slopes and direct water for treatment.
- A grade stabilization structure to reduce erosion and sedimentation in diversions, lined waterways and grassed waterways.
- Grassed waterway to stabilize conveyance of runoff.
- A lined waterway using erosion resistant materials in waterways to stabilize conveyance of runoff.
- Mulching to reduce erosion and facilitate establishment of vegetative cover.
- Runoff management systems to control excess runoff, including the use of erosion control measures.
- Sediment basins to capture and detain runoff.
- A structure for water control consisting of culverts to safely convey runoff under roads.

The sediment basin shown on the Conservation Plan (**Figure 4-4**) that is identified as a Town of Middletown Practice has recently been constructed by the Town of Middletown as part of their Maidford River BMP implementation project.

NRCS estimates that the total project costs for the features to be constructed on the Hoogendoorn site is $307,276, with $230,457 eligible to be reimbursed by NRCS upon successful completion of construction. For Town of Middletown-owned practices, NRCS estimated total construction costs for those features to be $101,263, with $76,138 eligible to be reimbursed by NRCS.

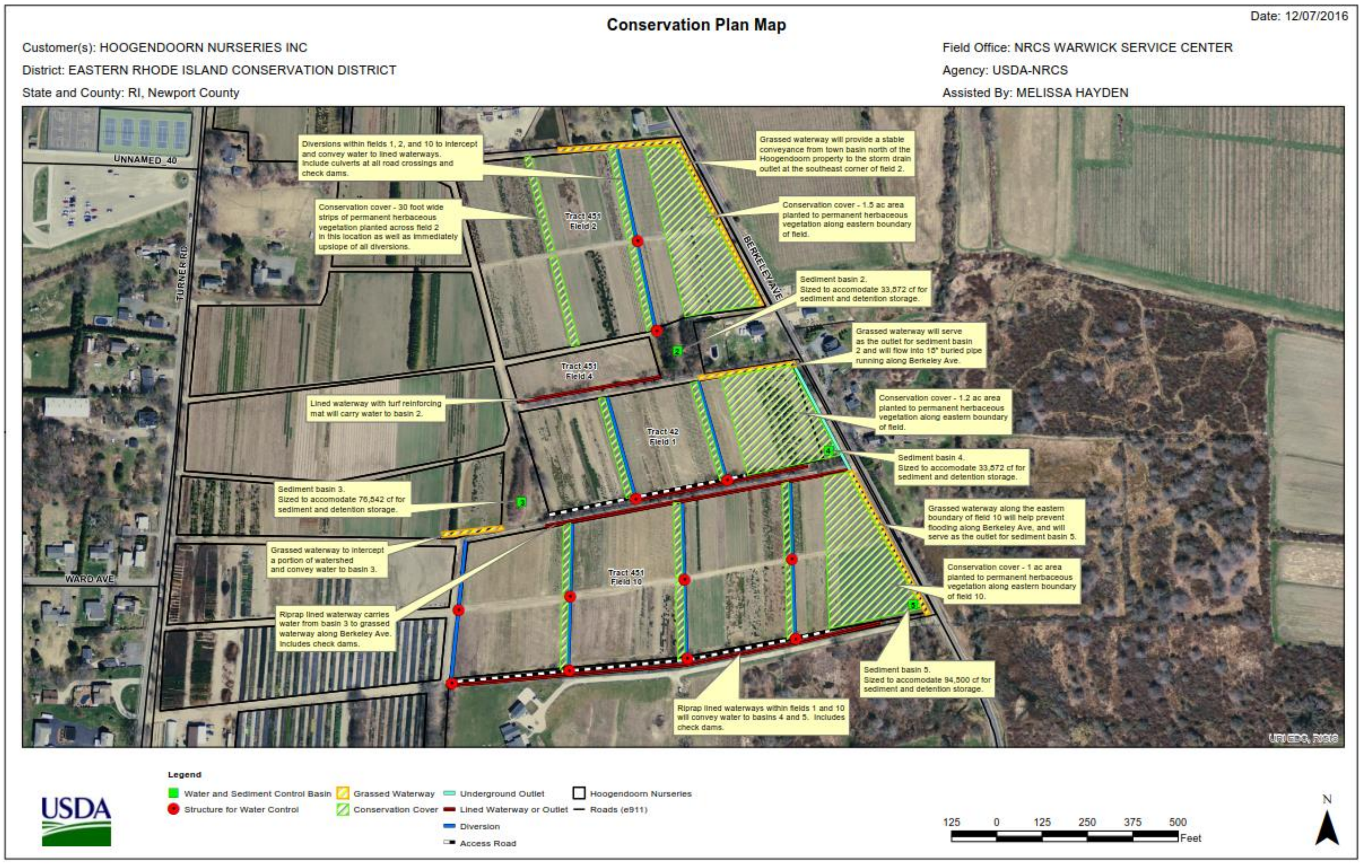

Figure 4-4. NRCS Conservation Plan for Hoogendoorn Nurseries

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Peabody Beach, Middletown

Third Beach Road slopes from the Norman Bird Sanctuary property to Peabody Beach, where the road flattens out. The runoff that is conveyed down Third Beach Road drains across the road and through a break in the sand dune to the beach. This runoff often results in significant erosion along the edge of the road at the bottom of the hill and across the pedestrian access to Peabody Beach. Icing is also common during freezing temperatures where runoff crosses the road in front of the beach.

Stormwater quality from this runoff also likely impacts Peabody Beach. This beach has experienced closures because of elevated levels of bacteria (**Figure 2-8**).

The goal of this project is to develop stormwater controls to both control erosion and icing as well as to improve water quality. While no design has been developed, this BMP could consist of a linear infiltration trench/sand filter adjacent to the road with a stabilized conveyance to safely convey to the beach flows greater than the system's capacity.

Almy Pond, Newport

Almy Pond currently has a TMDL (RIDEM, 2007) in place for phosphorous which is causing algal growth and eutrophic conditions in the pond. The City has retained PARE Corporation to develop a plan to reduce phosphorous loadings to the pond. They are currently completing the design of a pilot-study of a set of new stormwater BMPs in the northern part of the watershed. These proposed controls include deep sump catch basins, hydrodynamic separators, adsorption media filters, tree filters and filter strips. The City received a $250,000 grant for pilot testing green infrastructure in this watershed, and is contributing an additional $250,000 in matching contributions for this project.

The Aquidneck Land Trust does control a conservation easement abutting Almy Pond and Spouting Rock Road off of Coggeshall Avenue (**Figure 4-5**). While no design has been developed for this site, the Aquidneck Land Trust easement could be used to develop additional BMPs to manage stormwater, and at least some pavement removal could be performed along Spouting Rock Drive. This work would need to be coordinated with the City and their ongoing work in this watershed.

Figure 4-5. Aquidneck Land Trust Conservation Easement

Miantonomi Memorial Park, Newport

The Aquidneck Island Planning Commission and the City of Newport have developed a conceptual design for a new filter berm and bioretention basin at Miantonomi Memorial Park in Newport (the Park). The 2.5-acre portion of the Park where this design applies is along Hillside Avenue, between Kennedy Street and Eisenhower Street. This area is currently a developed lawn with trees along its perimeter. The conceptual design includes a filter berm along the western boundary and a bioretention basin at the low point along the eastern boundary. The conceptual design also re-grades the lawn area to a uniform slope, which promotes sheet flow and the use of the area as playing fields. **Figure 4-6** depicts existing conditions and the conceptual design.

Figure 4-6. Conceptual BMP for Miantonomi Memorial Park, Newport

The new filter berm and bioretention basin will improve existing conditions by managing and treating runoff. The filter berm will collect runoff from upland areas and evenly distribute it to uniformly flow over the playing fields, which will have a slope that promotes drainage. Under existing conditions, runoff floods at the location of the proposed filter berm, and the playing field does not have a slope that promotes drainage from the area. The new bioretention basin will be at the localized low-point of the area and collect runoff from the playing field. In addition to managing runoff, the basin will also treat for TSS, TN, and TP. Depending on results from future subsurface soil investigations, the bioretention area may also have the capacity to infiltrate into the underlying soil matrix. The project currently has a budget for $125,000; however, the AIPC and the City of Newport have submitted a grant application for further funding of the project.

Driftways – Multiple Locations

Driftways are public boat launch areas for small vessels that can be hand launched. They are important features that both maintain views and provide access to the waterfront. Driftways can also provide some flood protection by allowing storm surge to flow between structures. Although there are multiple driftways that could benefit from structural BMPs to control stormwater, a driftway located at Pine Street in Newport provides an example of such a project. The AIPC and the City of Newport have developed a conceptual design for a bioretention measure at the western most portion of Pine Street. The 5,000± SF site is directly south of Battery Park and west of Washington Street. Existing site features include a 20± foot wide paved driveway, a wooden guard rail, and steps that provide access to the beach. The conceptual design proposes to replace the paved driveway with a pedestrian access path and bioretention measures. The new bioretention measures will improve existing conditions by capturing and treating runoff that currently flows untreated directly to Dyer Point. Under proposed conditions, runoff from Washington Street will enter the bioretention measure at the upgradient portion of the site, and as runoff passes through the bioretention media, the measures will treat the runoff for TSS, TN, and TP. At the outlet of the bioretention, runoff will flow non-erosively to Dyer Point. Figures 4-8 and 4-9 show the potential site for driftway improvements on Pine Street and would be typical of driftway improvements at other locations.

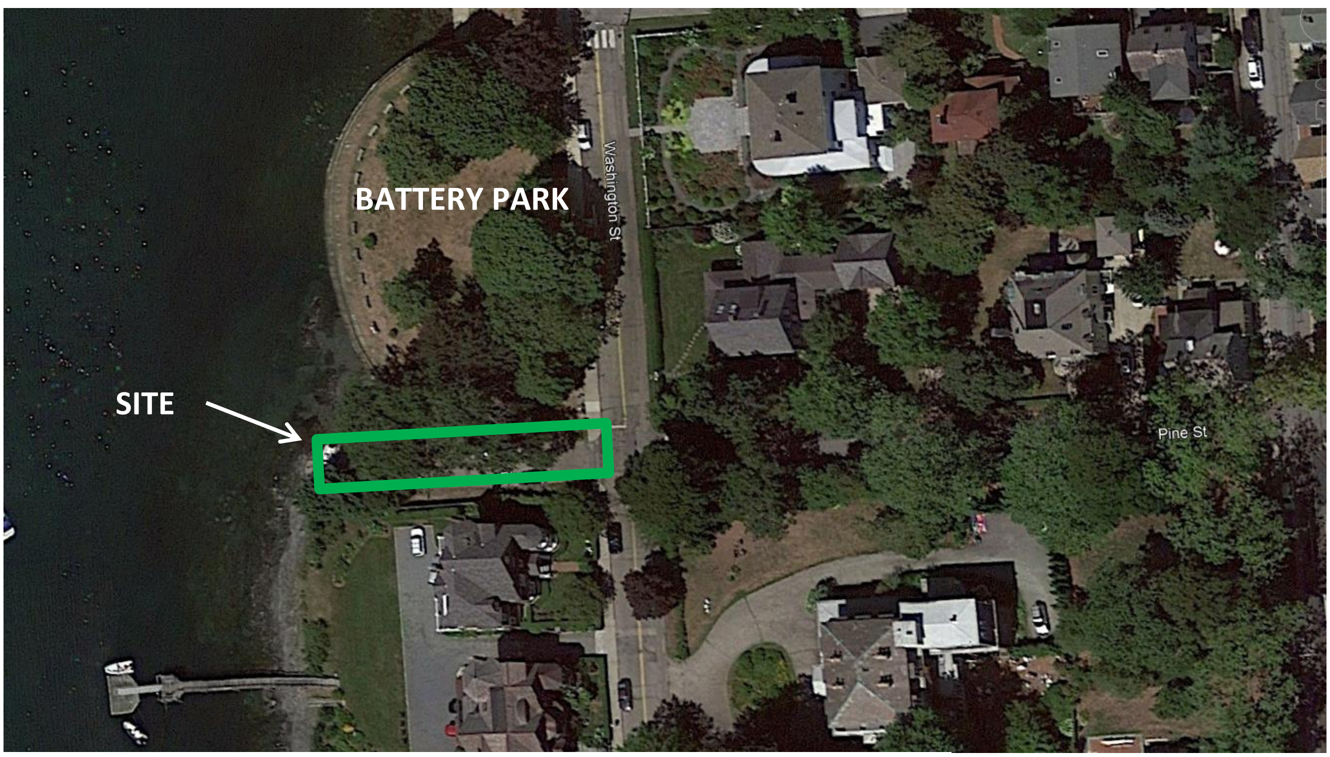

Figure 4-8. Driftway at Pine Street, Newport

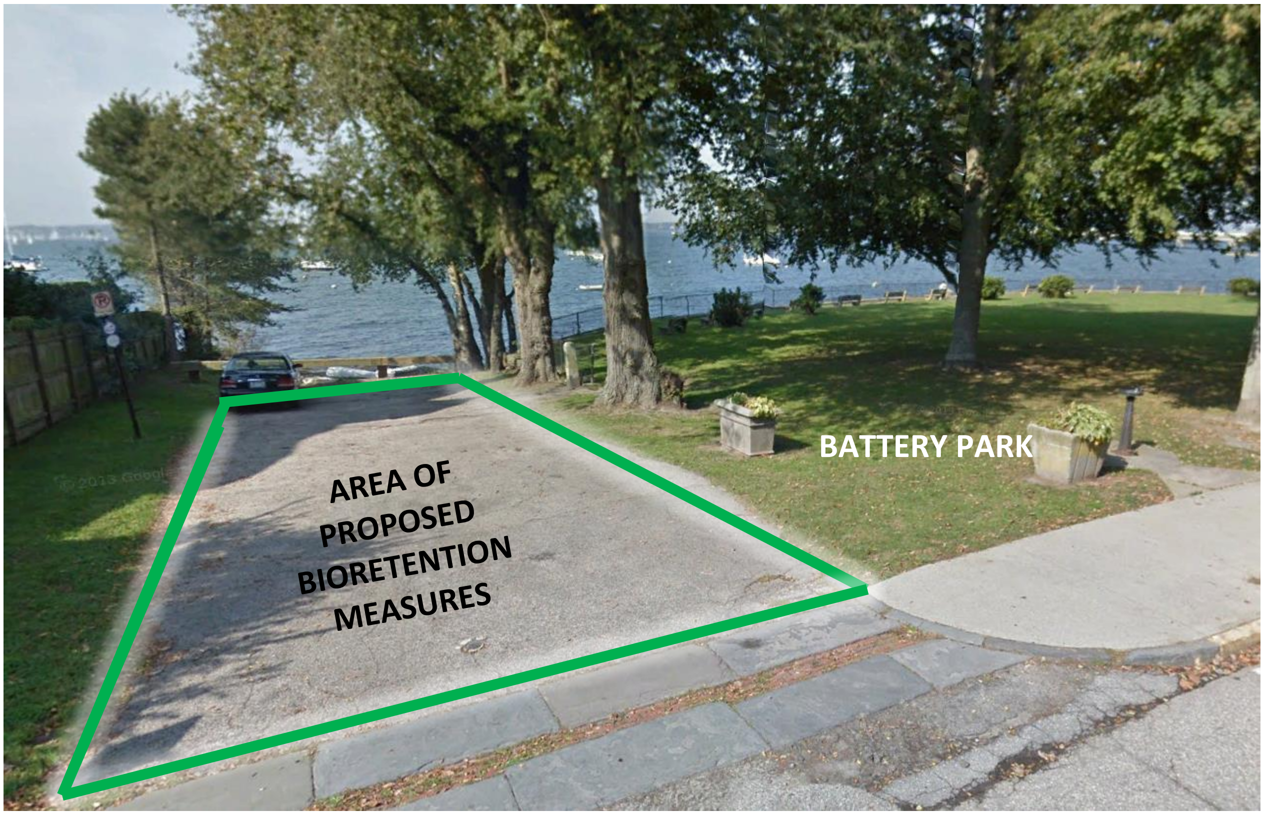

Figure 4-9. Proposed Area of Bioretention BMP at Pine Street Driftway

Animal Exclusion Fencing – Island Wide

Although not strictly a coastal BMP, the installation of fencing to exclude animals from both riparian areas and waterbodies is a management practice that would reduce nutrient, sediment, and bacteria inputs into inland waters on the Island. In areas where livestock currently utilize streams for water, the construction of fencing to prohibit direct access to the water and provision of alternative drinking water for livestock on pasture would benefit both buffer areas and waterbodies. Prohibiting animals from accessing the water prevents direct deposition of manure, and consequently bacteria and other potential pathogens, as well as nutrients, into the water. In addition, prohibiting or grazing/loafing along the banks prevents erosion of the shoreline and allows for establishment of a buffer area. In addition to reducing sediment load to streams, reducing erosion can also limit the transport of nutrients and bacteria that adhere to soil particles.

Figure 4-10. Example of Single Strand Electrified Livestock Exclusion Fencing (Source: Virginia Cooperative Extension, 2012)

5 Priority Actions to Restore Water Quality on Aquidneck Island

5.1 What is Stormwater Management?

Water is often called the “universal solvent,” meaning that it has the ability to dissolve more substances than any other liquid. This means that wherever water goes, through the air, or across the ground, it dissolves and carries with it a variety of substances, both good and bad. In the case of stormwater, the ultimate discharge point is typically a nearby lake, river, stream, wetland, or estuary, many times with little to no treatment to remove pollutants picked up in its journey to a discharge point.

Stormwater management is a comprehensive approach to mitigate the potential negative impacts of stormwater. To accomplish this, a stormwater management program makes use of “Best Management Practices,” or BMPs, to alter behaviors, prevent pollution, and treat water to improve water quality.

BMPs are methods, structures or techniques that have been identified to be the most practical and effective means to prevent or treat pollution before it reaches a waterbody. BMPs can be both structural, such as an infiltration basin, and non-structural, such as a public education program aimed at cleaning up after pets. BMPs can be tailored to specific audiences, sites, or pollutants of concern depending on individual site constraints and are typically recommended in combination to minimize pollution impacts and maximize positive impacts.

Non-structural BMPs prevent pollution from getting into stormwater by reducing sources of pollutants. Source reduction can occur by physically eliminating pollution sources, such as Illicit Discharge Detection and Elimination (IDDE) programs that aim to identify and remove illicit discharges to storm drains that could carry sewage and other pollutants. Increased maintenance of the stormwater conveyance system, including street sweeping and catch basin cleaning, can also represent a non-structural technique used to physically remove pollutants prior to their incorporation into stormwater and discharge to water resources.

Other non-structural BMPs focus on altering behaviors to help reduce pollutant sources. Nutrient management programs are a key tool that targets the reduction of fertilizers in residential,

Typical Non-Structural BMPs

Street Sweeping
Nutrient Management Programs
Stormwater Education
Buffer Protection
IDDE
Spill Prevention/Cleanup
Minimize/Reduce Impervious Surfaces

Typical Structural BMPs

Bioretention
Sand Filters
Infiltration Basins
Infiltration Chambers
Porous Pavement/Pavers
Bioreactors
Wet Vegetated Treatment Systems (WVTS)

commercial, and agricultural settings as a way to reduce nutrient loading. Similarly, stormwater education programs can help reduce and eliminate pollution sources through targeted messaging. Education programs often include topics such as pet waste disposal, proper disposal of yard wastes (grass clippings), and the proper maintenance of on-site wastewater treatment systems (septic systems).

In combination with non-structural practices, it is sometimes necessary to look at additional engineered solutions for stormwater treatment. Structural BMPs are those practices that are designed and constructed for the purpose of removing pollutants from stormwater. There is a wide range of practices available to treat stormwater. Infiltration and filtration are two primary treatment mechanisms used in most structural BMPs. Using infiltration, stormwater practices such as infiltration basins or chambers infiltrate stormwater into on-site or native soils to both treat stormwater as well as reduce peak runoff rates. When soils at a site are not suitable for infiltration, use of BMPs such as sand filters or WVTS, use filtering characteristics of a particular media (sand, soil, compost) to remove pollutants before the water is discharged to a receiving water.

Together, the combination of structural and non-structural BMPs make up an overall Stormwater Management Program. Only through a comprehensive approach can there be sustainable success in reducing and treating potential stormwater impacts to water quality, protecting and improving the quality of water resources on Aquidneck Island.

5.2 Decision Making Approach

Because the **Island Waters** project addresses the entirety of Aquidneck Island, a comprehensive island-wide approach to stormwater management is possible. This is a relatively unique situation since political boundaries, such as Town boundaries, and watershed boundaries very seldom align, making it difficult to coordinate municipal and stakeholder cooperation and involvement on a watershed scale.

In order to evaluate BMPs and create consensus among stakeholder participants it was important to develop a process that was inclusive, yet not too complex or cumbersome, allowing decisions and prioritization of actions for a comprehensive stormwater management plan to be identified. Through a series of workshops the project partners created and established a framework for evaluating and prioritizing structural BMPs across Aquidneck Island. Initially, the universe of BMP opportunities previously identified across the island was catalogued (**Section 4**). Once this pool of potential BMPs was identified and reviewed, a decision making tool was created to evaluate and prioritize BMPs based on the physical characteristics of the watershed where a BMP would be located, the characteristics of the BMP itself, and social/community concerns and opportunities. Each BMP was evaluated on 30 factors within the tool. The range of evaluation factors used in the tool allowed for consideration of more traditional evaluation criteria, such as maintenance costs and removal effectiveness, along with more subtle qualitative factors such as community acceptance and educational opportunity that often can have large impacts on the overall constructability or feasibility of a particular project.

5.3 The Prioritization Tool

The Prioritization Tool was developed by Fuss & O'Neill to provide a systematic, consistent, and transparent method of prioritizing stormwater BMP implementation on Aquidneck Island. Designed with flexibility in mind, it is intended for implementation at a watershed, jurisdictional, or regional scale. It incorporates as its starting point regional and national information on pollutant removal effectiveness and other BMP characteristics, along with professional engineering judgment of local conditions. Stakeholder input on more subjective factors associated with community priorities and opportunities is also included in the tool. The tool is designed to be transparent in its weighting of factors and calculations and is readily adaptable to changing conditions. As local conditions, stakeholder priorities, or funding opportunities may change, the prioritized list of BMPs can be revisited and updated accordingly. It is important to note, however, that the Tool is designed specifically situations where BMPs, both location and type, are already identified and is not intended to identify appropriate BMP types for particular locations or to identify locations for BMP installation. The Tool also does not utilize numeric pollutant removal efficiencies, but instead ranks relative effectiveness for a variety of pollutants, allowing for flexibility to adapt the tool to new or updated information on BMP performance.

5.3.1 Factors Considered

A wide range of decision-making elements, or metrics, are considered and fall into three broad categories: BMP Characteristics, Watershed Characteristics, and Community Factors (Table 5-1). BMP Characteristics and Watershed Characteristics reflect engineering judgment, anticipated cost and maintenance factors, and local environmental conditions. The Community category is one of two parts of the model that incorporates stakeholder input. Tables in **Appendix C** provide a more-detailed description of these metrics.

5.3.2 Design of the Tool

The Tool converts input from for each metric into a prioritized list (**Figure 5-1**). The list is based on scores for each BMP generated by the model that should be considered in relation to other BMPs under consideration. Each BMP receives a score for each metric that indicates its appropriateness for a given watershed and circumstance. These metric scores are modified by the metric's weight, or importance as determined by the Tool users. Weights should be carefully selected and reflect stakeholder priorities and values. Higher weights reflect greater importance to stakeholders or users of the tool. Scores are then summed across each category of metrics to provide a category score. Category scores contribute equally to a BMP's total score by default, although this can be modified as part of the Tool's flexibility. Higher total scores indicate greater suitability to local conditions and greater alignment with stakeholder values. A more detailed description of calculations used in the prioritization tool spreadsheet is included in **Appendix C**.

Table 5-1. List of Metrics Incorporated Into the Tool

Category	Metrics	
BMP Characteristics	• Permitting Challenges • Nutrient Removal Capacity • Capability of Treating Water Quality Volume • Sediment Removal Capacity • Capital Costs • Operation & Maintenance (O&M) • Sensitivity of BMP to routine/recommended O&M • Bacteria Removal Capability • Provide Flood Improvements	• Removal Capacity for Other Pollutants • Potential for Nuisance Conditions • Resistant to Storm Surge • Resistant to Rising Sea Levels • Resistant to Rising Groundwater • Resistant to Wetter Conditions • Resistant to Chronic Wind, Sand, Salt • Scale of Treatment
Watershed Characteristics	• Ownership • Impaired Waters • Drinking Water Supply • Public Bathing Beac • Shellfishing Area	• Imperviousness • Habitat Benefit • Primary Land Use Loading - Pollutant of Concern • Secondary Land Use Loading - Pollutant of Concern
Community	• Community Acceptance • Public Visibility	• Educational Opportunity • Conservation Benefits

5.4 Implementation of the Prioritization Tool for Structural BMPs

5.4.1 Process

Since 2005, multiple studies conducted by AIPC, ALT, and others have recommended various structural stormwater BMPs. Findings from these reports and input from stakeholders were compiled into the list of more than 90 BMPs across Aquidneck Island that are considered here and described in Section 4 of this report. Scores calculated in the Prioritization Tool for these 90 BMPs reflect engineering knowledge and judgment and stakeholder priorities modified by a set of weighting factors.

Values for these weighting factors were determined in consultation with project partners and stakeholders in the **Island Waters** project. **Table 5-2** shows the weights used in this implementation of the Tool, which were assigned in consultation with **Island Waters** stakeholders. Stakeholders identified nutrient removal capacity and proximity to impaired waters and drinking water supplies as highest priorities. Complexity of permitting and construction also factors heavily in developing the prioritized list of BMPs from the universe of 90 that had been initially identified.

Table 5-2. Weights for Each Prioritization Metric

BMP Characteristics		Watershed Characteristics		Community	
Metric	**Weight**	**Metric**	**Weight**	**Metric**	**Weight**
Permitting Challenges	3.00	Ownership	3.00	Community Acceptance	2.00
Nutrient Removal Capacity	2.00	Impaired Waters	2.00	Public Visibility	1.00
Capability of Treating Water Quality Volume	2.00	Drinking Water Supply	2.00	Educational Opportunity	1.00
Sediment Removal Capacity	2.00	Public Bathing Beach	1.50	Conservation Benefits	1.00
Capital Costs	1.50	Shellfishing Area	1.50		
Operation & Maintenance (O&M)	1.50	Primary Land Use Loading - Pollutant of Concern	1.50		
Sensitivity of BMP to routine/recommended O&M	1.50	Secondary Land Use Loading - Pollutant of Concern	1.00		
Bacteria Removal Capability	1.50	Imperviousness	1.00		
Provide Flood Improvements	1.50	Habitat Benefit	1.00		
Removal Capacity for Other Pollutants	1.00				
Resistant to Rising Sea Levels	1.00				
Resistant to Storm Surge	1.00				
Potential for Nuisance Conditions	1.00				
Resistant to Rising Groundwater	1.00				
Resistant to Wetter Conditions	1.00				
Resistant to Chronic Wind, Sand, Salt	1.00				
Scale of Treatment	1.00				

5.4.2 Results

Of the 90 BMPs under consideration, 14 were selected by project partners and other stakeholders as most-impactful and readily implemented. The BMP types that scored highly in the Tool varied with the local context. Filter berms, bioretention, WVTS, and buffer restoration are among the BMPs identified as high priority projects. In more developed areas, effectiveness of runoff reduction was the key process underpinning BMP selection. Where agricultural land uses dominate, filtration practices and WVTS scored highest. Structural BMPs identified for priority implementation are listed in **Table 5-3**. Prioritized BMPs were identified in all three Aquidneck Island municipalities.

Table 5-3. List of Prioritized and Alternate BMPs

Description and Location	BMP Identifiers	Receiving Water	Municipality
Filter Berms and Bioreactors, Tibbets Farm	MR_FB_1 & MR_FB_2 MR_B_1 & MR_B_2	Maidford River	Middletown
Conservation Plan, Hoogendoorn Nurseries	MR_O_3	Maidford River	Middletown
Conservation Plan, Newport Equestrian	N/A	Maidford River	Middletown
WVTS, Island Drive, Middletown	SP_W_1	Sisson Pond	Middletown
WVTS, Carriage Drive and Oakland Drive, Portsmouth	SM_W_1 SM_W_2	St. Mary's Pond	Portsmouth
Buffer Restoration, North Shore of St. Mary's Pond	SM_BU_1, SM_BU_2, & SM_BU_3	St. Mary's Pond	Portsmouth
Stormwater Improvements, Spouting Rock Drive, Newport	Almy	Almy Pond	Newport
Bioretention Practice, Miantonomi Park	Mianto	Narragansett Bay	Newport

5.5 Recommendations

The BMPs identified in **Section 5.4** (and described in detail in **Appendix D**) are currently scheduled to be designed, permitted and constructed over the next eighteen months. These BMPs were selected based on their ability to meet project criteria defined in the prioritization process, as well as being able to be readily implemented to meet funding-related time constraints. In addition to implementing this first round of BMPs, **Island Waters** stakeholders should consider several other recommendations to build on the momentum of the work completed to date and continue to address water quality issues on Aquidneck Island.

1. **Identify the Second Round of Best Management Practices.** Several structural BMPs have been identified as high priority but are not planned for the first round of implementation because of current available funding. These include:

    a. Bioretention at the Middletown Soccer Complex on Wyatt Road
    b. Implementation of improvements at the Spouting Rock Road in Newport that are not implemented in the first round
    c. Bioretention along the Cliff Walk near Marine Avenue in Newport
    d. Third site of buffer restoration along St. Mary's Pond.

    Current opinions-of-cost for these planned improvements is $475,000. Future grant programs such as the Southern New England Program (SNEP) are scheduled to be available at least for the near future. Rhode Island also typically approves a bond (e.g., Bay Watershed Restoration Fund (BWRF)) to finance grants to address stormwater quality projects. Given the water quality concerns on Aquidneck Island, future grant applications to finance **Island Waters** projects would be expected to be competitive.

Before implementing this next phase of structural BMPs, **Island Waters** stakeholders should revisit the prioritization tool and consider the following to confirm that the previously identified improvements should still be implemented:

a. Are the previously identified controls still the priority to implement with the next phase of improvements?
b. Are there any other improvements that would make sense to include in this next phase of improvements?

2. **Engage Private Property Owners Where BMPs are Now Planned.** Based on application of the prioritization tool, several BMPs on private property ranked higher than some of the BMPs that were selected for Phase 1 implementation due, in part, to their location on public-owned or controlled land. They typically consist of buffer restoration and other relatively simple management measures that can cost effectively address water quality issues, especially in the Maidford River watershed. While ALT maintains an easement on most of these properties, they do not have the level of control with that easement that would allow them to install water quality improvements without the consent of those private property owners.

   In order to take advantage of these relatively cost effective improvements on private property, we recommend that ALT engage these property owners to determine what projects these owners would support within the existing easements. Prioritization should be given to those sites consistent with ranking in the prioritization tool.

3. **Continue Engagement of Farming Community.** Agriculture is a significant source of nutrients and sediments contributing to impairments in Newport Water's source water supplies. NRCS (Natural Resources Conservation Service) and ERICD (Eastern Rhode Island Conservation District) provide programs to both educate and support farmers with technical and financial resources. Active promotion of these programs should continue, as well as actively engaging NRCS and ERICD to continue to commit resources to improving water quality on Aquidneck Island.

4. **Identify Potential Non-Structural Practices.** Non-structural practices can contribute as a cost effective approach to address non-point source pollutant loadings on Aquidneck Island. While attention has been focused on selecting structural BMPs to date, a future **Island Waters** workshop is recommended to identify potential non-structural BMPs that could also improve water quality in the watershed. As part of the **Island Waters** project, a non-structural BMP prioritization tool has also been developed for use by the watershed stakeholders to assist with selecting non-structural BMPs once they are identified.

5. **Identify Sustainable Funding Sources.** While the first phase of improvements that is recommended to be implemented as part of the **Island Waters** project funding includes a number of new structural BMPs, additional significant investment will be required to fully implement this suite of structural and non-structural water quality management practices identified through the **Island Waters** project. A workshop is scheduled for calendar year 2018 to identify potential mechanisms to fund the construction, as well as potentially operation and maintenance of these improvements.

6. **Coordinate with Agencies and NGOs to Implement Long-Term Monitoring Program.** While substantial water quality data has been collected to assess water quality and potential impairment on Aquidneck Island, AIPC should consider working with other project partners to organize ongoing water quality monitoring. This data could be used to both assess performance of newly constructed structural BMPs as well as assess improvement in receiving waters. This effort could be helpful in building support with the public to implement future controls after this initial project has been completed. Local colleges (e.g., Salve Regina) and environmental advocacy groups (e.g., Clean Ocean Access) have experience implementing monitoring programs and could potentially team with AIPC to implement a long-term monitoring plan.

7. **Consider MS4 Support.** RIDEM's MS4 general permit requires a number of potential actions for permit compliance (See Section 3) that AIPC may be able to provide to municipalities more cost effectively instead of municipalities completing these tasks on their own. These potential services include:

    a. Conducting public education programs. This could include preparing mailers or other informational material and activities to target communities, conducting public educational events, and engaging special interest groups within the community (e.g., farmers, horse owners, pet owners) on water quality issues.
    b. Conducting public participation programs. This could include conducting watershed clean ups, implementing sampling programs (such as that is currently done by Clean Ocean Access), or implementing a tree planting program in stream buffers, as well as other potential activities that could improve water quality.

Any actions that AIPC takes to improve water quality on Aquidneck Island should be coordinated with the municipalities and results shared (e.g. number of attendees at a meeting) such that municipalities can report it to RIDEM as part of their MS4 compliance efforts. If AIPC wants to provide MS4 support on the Island, conducting a workshop with municipalities to identify potential services that could best be shared between them is an important first step.

5.6 Transferability and Adaptation

The methodology developed as part of the **Island Waters** project for the consideration and prioritization of BMPs provides an opportunity for transferability throughout the southeast New England coastal watersheds and beyond. Transferability is a goal of the Southeast New England Coastal Watershed Restoration Grants Program since it allows for sharing of successes and challenges and encourages methods, techniques, and technologies to be shared. The best management practices identified for priority implementation on Aquidneck Island are well-established techniques and are transferable across several scales – Aquidneck Island, the Narragansett Bay watershed, and beyond. Their implementation on Aquidneck Island, especially if follow-up water quality monitoring is conducted, will further knowledge of BMP performance and provide information useful for implementation in other watersheds facing similar water quality challenges.

Adaptability, both within an individual watershed over time and for utilization among different watersheds, is important for long-term sustainability of a program. The ability to adapt to changing environmental conditions, including those associated with changing climate and weather patterns, and evolving community conditions including changes in land use, zoning, and land stewardship, help to ensure that established plans remain relevant and can be responsive to change. The prioritization tool, which can be customized to address the specific needs of a watershed and the community within that watershed, is specifically designed for adaptation over time as environmental and social conditions on the Island change. This framework can also be adapted to other geographic locations and communities and it specifically designed to allow decision-makers and stakeholders to identify and incorporate specific watershed and community factors in a systematic, quantitative way to help prioritize BMP implementation.

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Appendix A

Municipal MS4 Compliance

Table A-1. Summary of Newport MS4 Compliance Status

Minimum Control Measure	BMP Requirement	Responsible Parties / Departments	Program Highlights
Public Education and Outreach	• Implement ongoing public stormwater education program • Develop/acquire and disseminate educational materials • Incorporate measures for Stormwater Pollutants of Concern associated with impaired waters	Department of Utilities	• Dissemination of BMP education materials • City contracts the development of printed materials • The City solicits public input on drainage improvement studies and publication of those studies on city website
Public Involvement and Participation	• Provide public notice to solicit public comment for the annual reports	Department of Utilities	• City has implemented a Citizen Committee on wastewater and stormwater system improvements, reporting to City Council • The City has solicited public comment for its SWMPP • The City has held several public meetings on stormwater management and green infrastructure pilot testing
Illicit Discharge Detection and Elimination (IDDE)	• Establish legal authority necessary to prohibit, investigate and eliminate illicit discharges • Develop a list and map of all stormwater outfalls • Maintain list of locations of catch basins, manholes, pipes within system used to investigate illicit discharges • Develop and implement written Illicit Discharge Detection and Elimination (IDDE) Plan, including illegal dumping • Identify priority areas to locate and remove the source of illicit discharges • Conduct dry –weather screening and sampling of MS4 outfalls for illicit discharges • Inform public employees, businesses and general public about hazards associated with illegal discharges	Department of Utilities	• The City has an existing ordinance which was adopted on October 11, 2006 • All outfalls mapped as of January 2010 • Written IDDE procedure adopted • All catch basins and manholes inspected for illicit connections/IDDE annually • Dry weather surveys to meet High and Low Water Illicit Discharge requirement completed October, 2016 • SOPs in place for reporting suspected illicit discharges to RIDEM • Public employees receive annual training on spill prevention and control, and hazardous waste contingency plans • No illicit discharge complaints were received and no illicit discharges were detected in 2016
Construction Site Storm Water Runoff Control	• Establish legal authority to implement construction site stormwater runoff control using BMPs and LIDs appropriate for site conditions to minimize water quality impacts • Develop and implement interagency coordination procedures • Require site operators to develop and implement a Storm Water Pollution Prevention Plan and control wastes • Perform site reviews and inspections • Incorporate public involvement into development activities • Notify developers of DEM's construction general permit	Department of Utilities Assistance from Building Official	• The City has adopted an ordinance in 2007 establishing the legal authority to regulate this MCM • The City receives several construction applications each year that trigger plan reviews, site inspections and, where warranted, notice of violations leading to corrective action
Post-Construction Storm water Management in New Development and Redevelopment	• Establish legal authority requiring that applicants for development and redevelopment within the Town use erosion and sediment control measures • Require runoff reduction and LID measures in new development and redevelopment appropriate for the community • Develop and implement procedures for site plan review to ensure compliance with DEM's Stormwater Design and Installation Manual • Develop and implement a maintenance plan for ensuring the long-term effectiveness of stormwater basins and other treatment structures	Department of Utilities	• The City adopted an ordinance on December 10, 2008 establishing the legal authority to regulate this MCM • The City is developing a spreadsheet of known private BMPs to better manage permitting/compliance
Pollution Prevention and Good Housekeeping in Municipal Operations	• Identify all operations with or potential for a point source stormwater discharge to MS4 with potential to introduce pollutants • Develop and implement program to reduce stormwater volume from MS4 operator • Employee training • MS4 property and operations maintenance • Develop and implement a program to control the contribution of pollutants to its MS4 from commercial, industrial, municipal, institutional or other facilities, not otherwise authorized by DEM general permits	Department of Utilities	• The City has GIS mapping of City-owned BMPs and catch basins and all BMPs were inspected/cleaned in 2016 • In 2016, 2,660 catch basins were inspected, 1,268 cleaned, which removed 396.6 tons of sand/debris • In 2016, 188 road miles were swept, removing 454.5 tons of sand/debris • There were 23 municipal employees received SWPPP or SPCC training in 2016

Table A-2. Summary of Middletown MS4 Compliance Status

Minimum Control Measure	BMP Requirement	Responsible Parties or Departments	Program Highlights
Public Education and Outreach	• Implement ongoing public stormwater education program • Develop/acquire and disseminate educational materials • Incorporate measures for Stormwater Pollutants of Concern associated with impaired waters	Public Works	• Dissemination of IDDE, fertilizer use, and ISDS maintenance education materials via town website, public buildings, mailings • Maintenance of website clearinghouse for educational materials • Information on proper disposal and pump-out procedures provided to lessees by the Harbor Master
Public Involvement and Participation	• Provide public notice to solicit public comment for the annual reports	Public Works	• The Town solicited public comments on SWMPP and Annual Report • The Town has conducted public meetings on stormwater issues • Regularly scheduled Roads and Utilities Committee meetings offer additional opportunities for public involvement • Cleanup events held with various organizations
Illicit Discharge Detection and Elimination (IDDE)	• Establish legal authority necessary to prohibit, investigate and eliminate illicit discharges • Develop a list and map of all stormwater outfalls • Maintain list of locations of catch basins, manholes, pipes within system used to investigate illicit discharges • Develop and implement written Illicit Discharge Detection and Elimination (IDDE) Plan, including illegal dumping • Identify priority areas to locate and remove the source of illicit discharges • Conduct dry –weather screening and sampling of MS4 outfalls for illicit discharges • Inform public employees, businesses and general public about hazards associated with illegal discharges	Public Works Assistance from Planning Dept	• The Town has an existing ordinance which was adopted on February 21, 2006 • All outfalls were mapped as of March 2009 • Written IDDE procedures were adopted in 2009 and incorporated in the SWMPP • All catch basins and manholes were inspected for illicit connections in 2007 • Dry weather surveys of outfalls completed in 2009 • SOPs to report illicit discharges to RIDEM • The Town maintains a home inspection program for illegal tie-ins to sanitary sewer system • The Town mandates pre-construction inspections for illegal connections • Public employees recieve annual training on spill prevention and control and hazardous waste contingency plans • No illicit discharges were detected in 2016
Construction Site Storm Water Runoff Control	• Establish legal authority to implement construction site stormwater runoff control using BMPs and LIDs appropriate for site conditions to minimize water quality impacts • Develop and implement interagency coordination procedures • Require site operators to develop and implement a Storm Water Pollution Prevention Plan and control wastes • Perform site reviews and inspections • Incorporate public involvement into development activities • Notify developers of DEM's construction general permit	Building Official	• The Town has an existing ordinance which was adopted on February 21, 2006 • The Town receives several construction applications each year that trigger plan reviews, site inspections and, where warranted, notice of violations leading to corrective action. • No complaints were received and no violations were issued in 2016
Post-Construction Storm water Management in New Development and Redevelopment	• Establish legal authority requiring that applicants for development and redevelopment within the Town use erosion and sediment control measures • Require runoff reduction and LID measures in new development and redevelopment appropriate for the community • Develop and implement procedures for site plan review to ensure compliance with DEM's Stormwater Design and Installation Manual • Develop and implement a maintenance plan for ensuring the long-term effectiveness of stormwater basins and other treatment structures	Building Official	• The Town has an existing ordinance which was adopted on February 21, 2006 • The Town maintains a GIS database of structural BMPs along with ownership and maintenance responsibility and existing condition • The Town is conducting a stormwater utility funding study aimed at funding the highest priority BMPs identified during 2013 Bailey Brook and 2016 Maidford River studies • No violations, issues, or complaints received in 2016
Pollution Prevention and Good Housekeeping in Municipal Operations	• Identify all operations with or potential for a point source stormwater discharge to MS4 with potential to introduce pollutants • Develop and implement program to reduce stormwater volume from MS4 operator • Employee training • MS4 property and operations maintenance • Develop and implement a program to control the contribution of pollutants to its MS4 from commercial, industrial, municipal, institutional or other facilities, not otherwise authorized by DEM general permits	Public Works	• The Town maintains a GIS database of publicly-owned BMPs • All publicly-owned BMPs inspected and cleaned in 2016 • One publicly-owned detention pond was retrofitted to improve functioning 2016 • In 2016, all catch basins were inspected • In 2016, ~250 culverts cleaned of debris/sediment • The Town also performs cleanups following storm events • In 2016, all Town roads were swept • Two training events were held for all municipal employees with SWMPP responsibilities

			• The Town held an additional training for all DPW employees on the elimination of the winter-time application of road sand in 2016

Table A-3. Summary of Portsmouth MS4 Compliance Status

Minimum Control Measure	BMP Requirement	Responsible Parties / Departments	Program Highlights
Public Education and Outreach	• Implement ongoing public stormwater education program • Develop/acquire and disseminate educational materials • Incorporate measures for Stormwater Pollutants of Concern associated with impaired waters	Planning	• The Town maintains a website for public stormwater education
Public Involvement and Participation	• Provide public notice to solicit public comment for the annual reports	Planning	• The Town has solicited comment on annual reports
Illicit Discharge Detection and Elimination (IDDE)	• Establish legal authority necessary to prohibit, investigate and eliminate illicit discharges • Develop a list and map of all stormwater outfalls • Maintain list of locations of catch basins, manholes, pipes within system used to investigate illicit discharges • Develop and implement written Illicit Discharge Detection and Elimination (IDDE) Plan, including illegal dumping • Identify priority areas to locate and remove the source of illicit discharges • Conduct dry –weather screening and sampling of MS4 outfalls for illicit discharges • Inform public employees, businesses and general public about hazards associated with illegal discharges	Stormwater coordinator, DPW director, Planning Dept	• The Town has an existing IDDE ordinance that was passed on April 28, 2008 • All outfalls have been mapped as of 2008 • Connectivity mapping has been completed for 33 of 70+ outfalls • Dry weather surveys of outfalls were completed in 2007 • In 2011, 5 illicit discharges detected, 3 of which were eliminated • In 2011, 3 violations were issued, 1 of which was resolved
Construction Site Storm Water Runoff Control	• Establish legal authority to implement construction site stormwater runoff control using BMPs and LIDs appropriate for site conditions to minimize water quality impacts • Develop and implement interagency coordination procedures • Require site operators to develop and implement a Storm Water Pollution Prevention Plan and control wastes • Perform site reviews and inspections • Incorporate public involvement into development activities • Notify developers of DEM's construction general permit	Building Official	• The Town passed an ordinance March 28, 1993, amended in September 2010 • The Town receives several construction applications each year that trigger plan reviews, site inspections and, where warranted, notice of violations leading to corrective action. • No violations issued and only one (1) complaint received and investigated in 2011
Post-Construction Storm water Management in New Development and Redevelopment	• Establish legal authority requiring that applicants for development and redevelopment within the Town use erosion and sediment control measures • Require runoff reduction and LID measures in new development and redevelopment appropriate for the community • Develop and implement procedures for site plan review to ensure compliance with DEM's Stormwater Design and Installation Manual • Develop and implement a maintenance plan for ensuring the long-term effectiveness of stormwater basins and other treatment structures	Planning	• No ordinance in place as of 2011 report • One (1) post-construction review completed in 2011 • The Town received 1 complaint and subsequently investigated • Fifteen Operation and Maintenance inspections were completed in 2011
Pollution Prevention and Good Housekeeping in Municipal Operations	• Identify all operations with or potential for a point source stormwater discharge to MS4 with potential to introduce pollutants • Develop and implement program to reduce stormwater volume from MS4 operator • Employee training • MS4 property and operations maintenance • Develop and implement a program to control the contribution of pollutants to its MS4 from commercial, industrial, municipal, institutional or other facilities, not otherwise authorized by DEM general permits	Not specified	• GIS mapping of City-owned BMPs and catch basins • All BMPs inspected and cleaned in 2011 • All catch basins inspected and cleaned in 2011 • All roads are swept annually • The Town maintains regular litter pick-up • The Town provides on the job training to municipal employees

Appendix B

BMP Descriptions

Appendix B

This appendix includes information on the BMPs recommended for Sisson Pond, Lawton Valley Reservoir, and North Easton Pond and maps of their location within the watershed.

Table B-1. Summary of BMPs across the three watersheds

BMP Type	Example	Description
Bioretention		• Bioretention cells are vegetated basins that are designed to capture and treat the water quality volume within dry cells formed by check dams or other means • Stormwater filters through the cells and is either returned to the storm drain system or infiltrated, removing nutrients, metals, and pathogens
Wet Vegetated Treatment System (WVTS)		• A WVTS treats the water quality volume in one or more permanent pools with emergent vegetation • Cells within the system detain stormwater where pollutants, especially nutrients and bacteria, settle or are taken up by the rhizomes of the emergent vegetation
Buffer Restoration		• A healthy riparian buffer is a forested area adjacent to a waterbody acts as a filter to remove sediment and nutrients from stormwater • Grasses, shrubs, and trees absorb nutrients from stormwater while their roots protect the stream bank from erosion
Filter Berm	 image: RL Guffey (2012)	• Filter berms consist of a stable, permeable berm such as gravel or compost, placed at the downgradient edge of an agricultural field. Runoff would temporaily pool behind the berm and then slowly drain through it • The filter media in the berm serves to both filter the runoff from the fields and provide some opportunity for cation exchange of dissolved pollutants

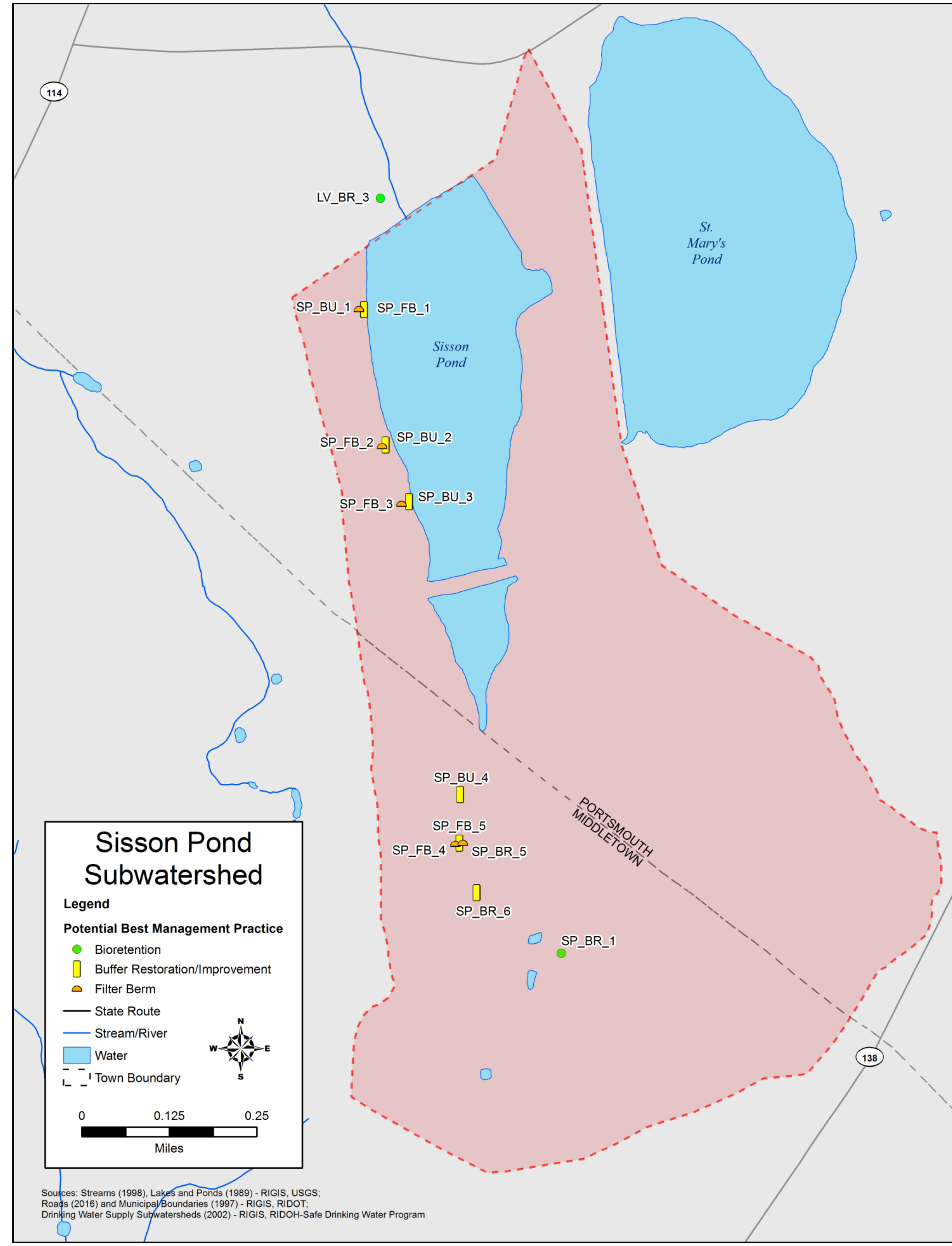


Figure B-1. Recommended BMPs in the Sisson Pond Subwatershed

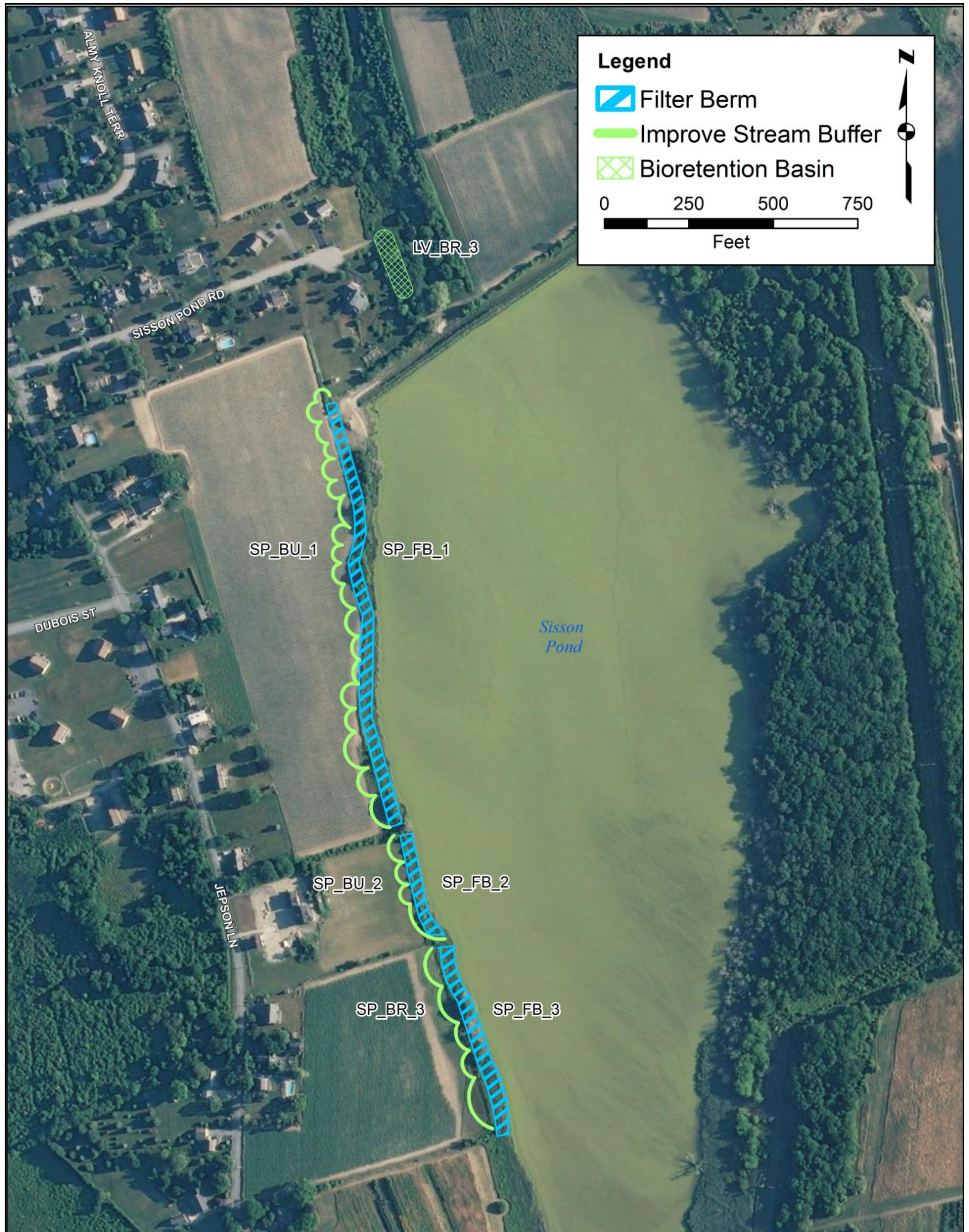


Figure B-2. Filter berm and buffer restoration in the northern part of the Sisson Pond Subwatershed

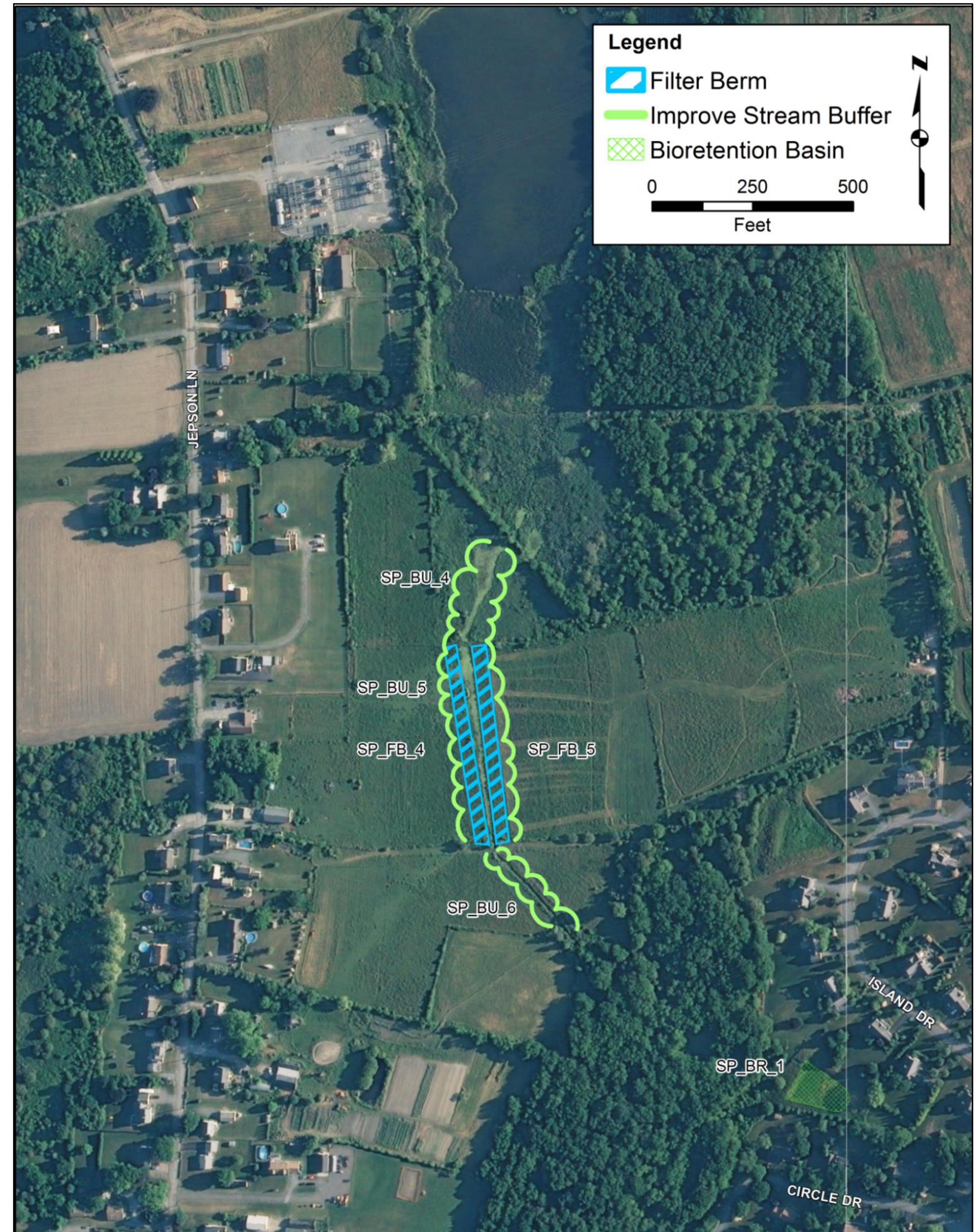


Figure B-3. Filter berm and buffer restoration in the southern part of the Sisson Pond Subwatershed

Table B-2. Summary of Lawton Valley Reservoir BMPs

BMP Type	Example	Description
Bioretention		• Bioretention cells are vegetated basins that are designed to capture and treat the WQV within dry cells formed by check dams or other means • Stormwater filters through the cells and is either returned to the storm drain system or infiltrated, effectively removing nutrients metals and pathogens
Wet Vegetated Treatment System (WVTS)		• A healthy riparian buffer is a forested area adjacent to a waterbody acts as a filter to remove sediment and nutrients from stormwater • Cells within the system detain stormwater where pollutants, especially nutrients and bacteria, settle or are taken up by emergent vegetation

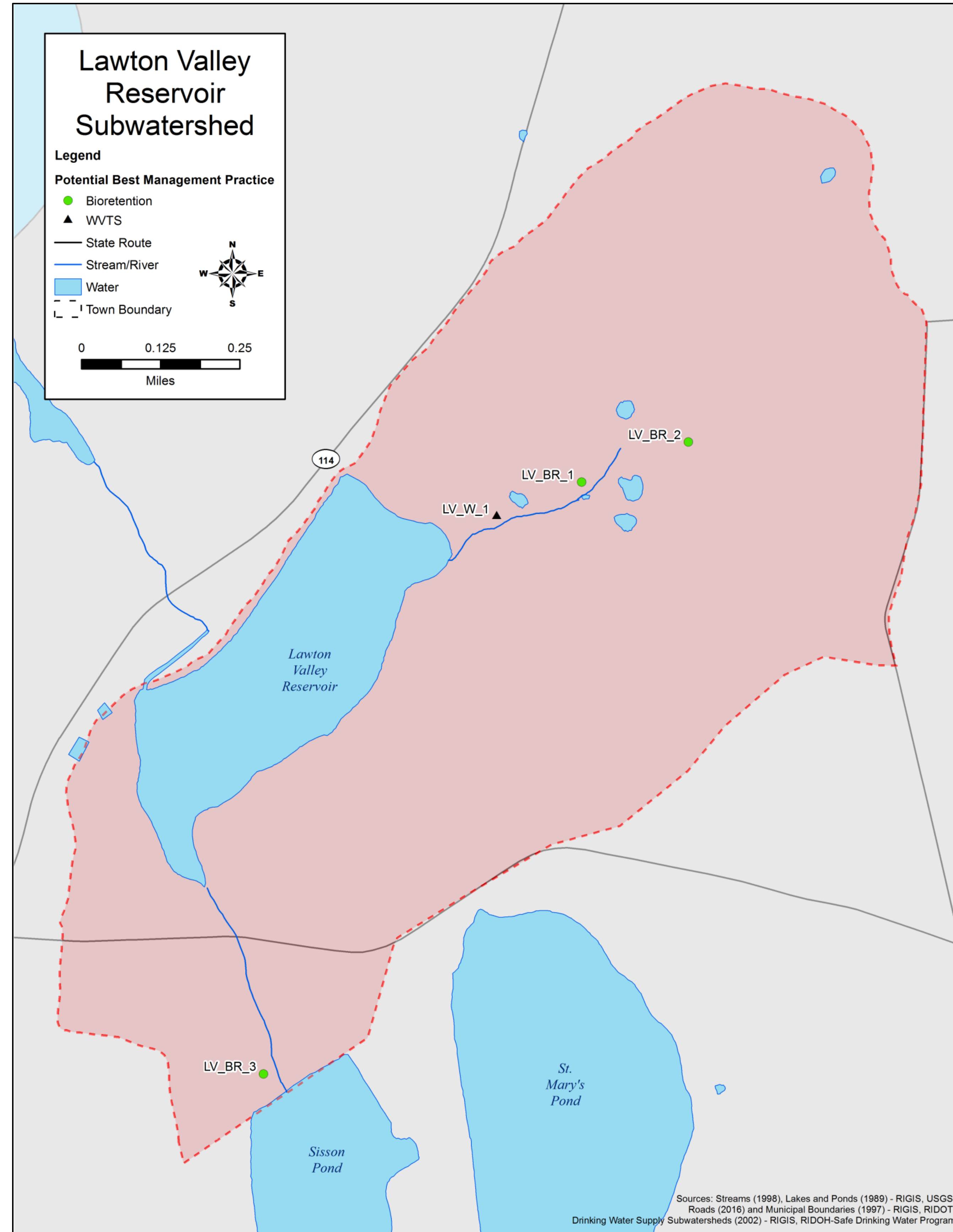


Figure B-4. Bioretention and WVTS in the Lawton Valley Reservoir Subwatershed

Figure B-5. WTVS and bioretention in the Lawton Valley Reservoir Subwatershed

Table B-3. Summary of North Easton Pond BMPs

BMP Type	Example	Description
Bioretention		• Bioretention cells are vegetated basins that are designed to capture and treat the WQV within dry cells formed by check dams or other means • Stormwater filters through the cells and is either returned to the storm drain system or infiltrated, effectively removing nutrients metals and pathogens

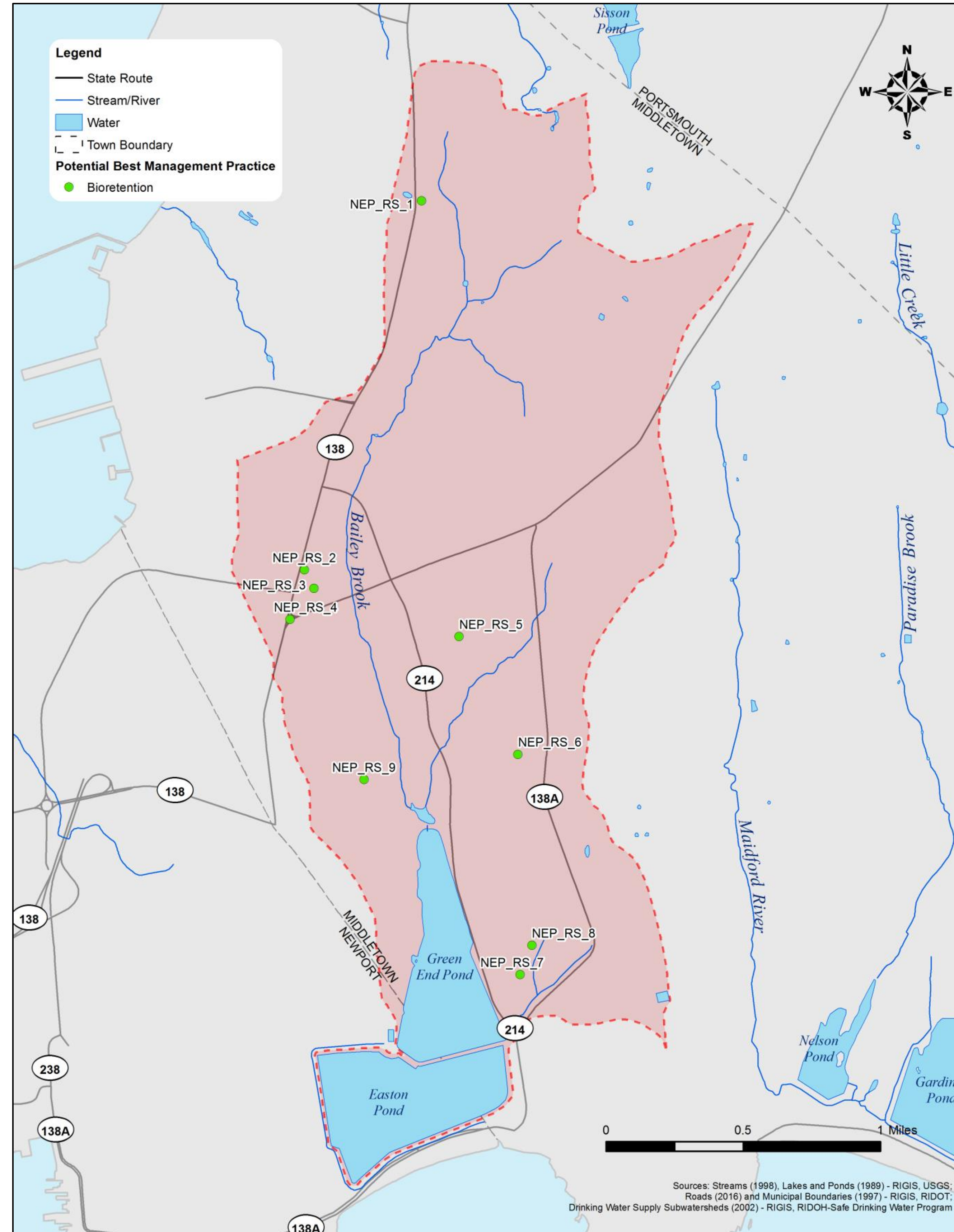


Figure B-6. Bioretention in North Easton Pond Subwatershed

Figure B-7. Bioretention at W Main Rd and Oliphant Ln

Figure B-8. Bioretention near E Main Rd and W Main Rd

Figure B-9. Bioretention at Middletown High School

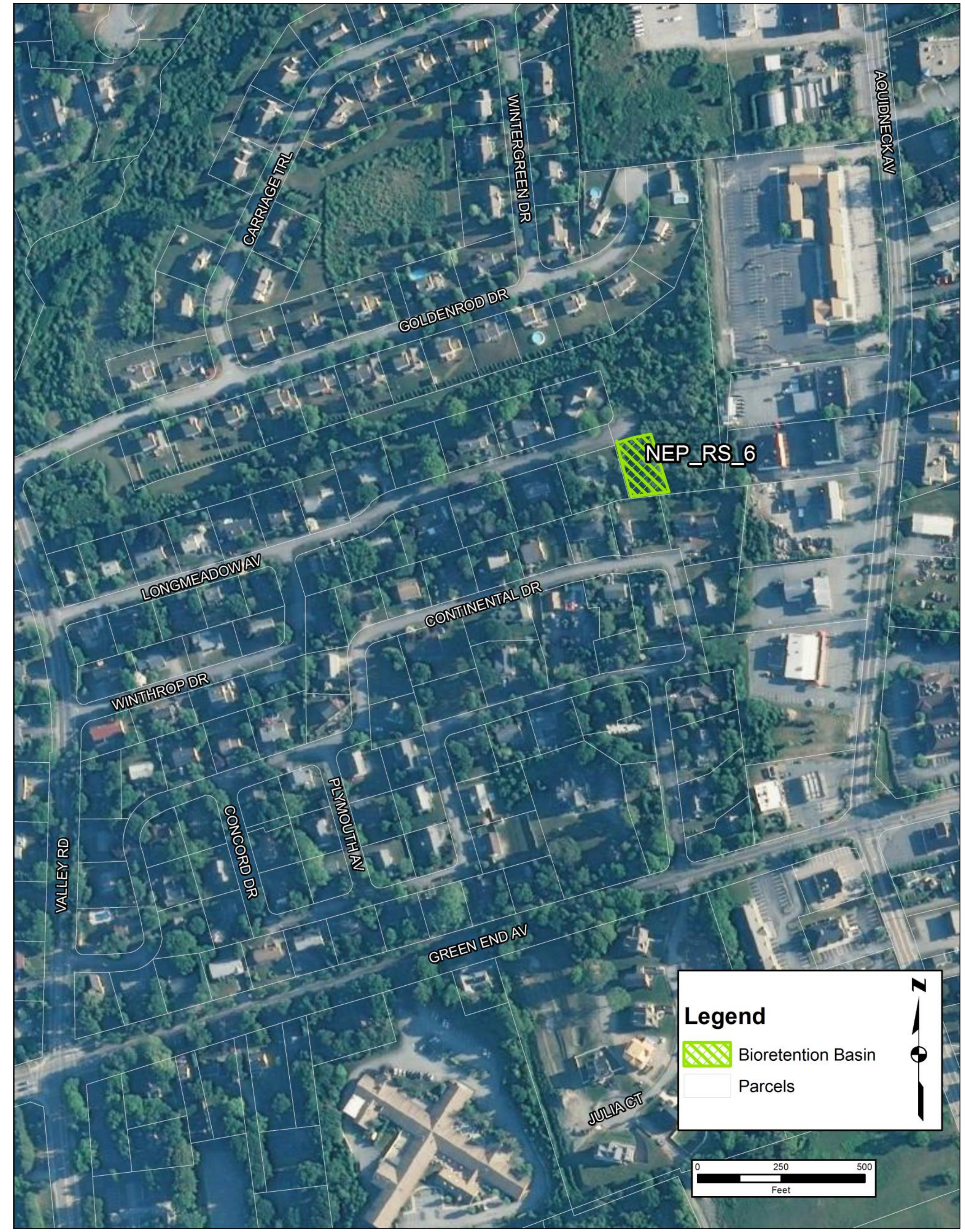


Figure B-10. Bioretention at the end of Longmeadow Ave

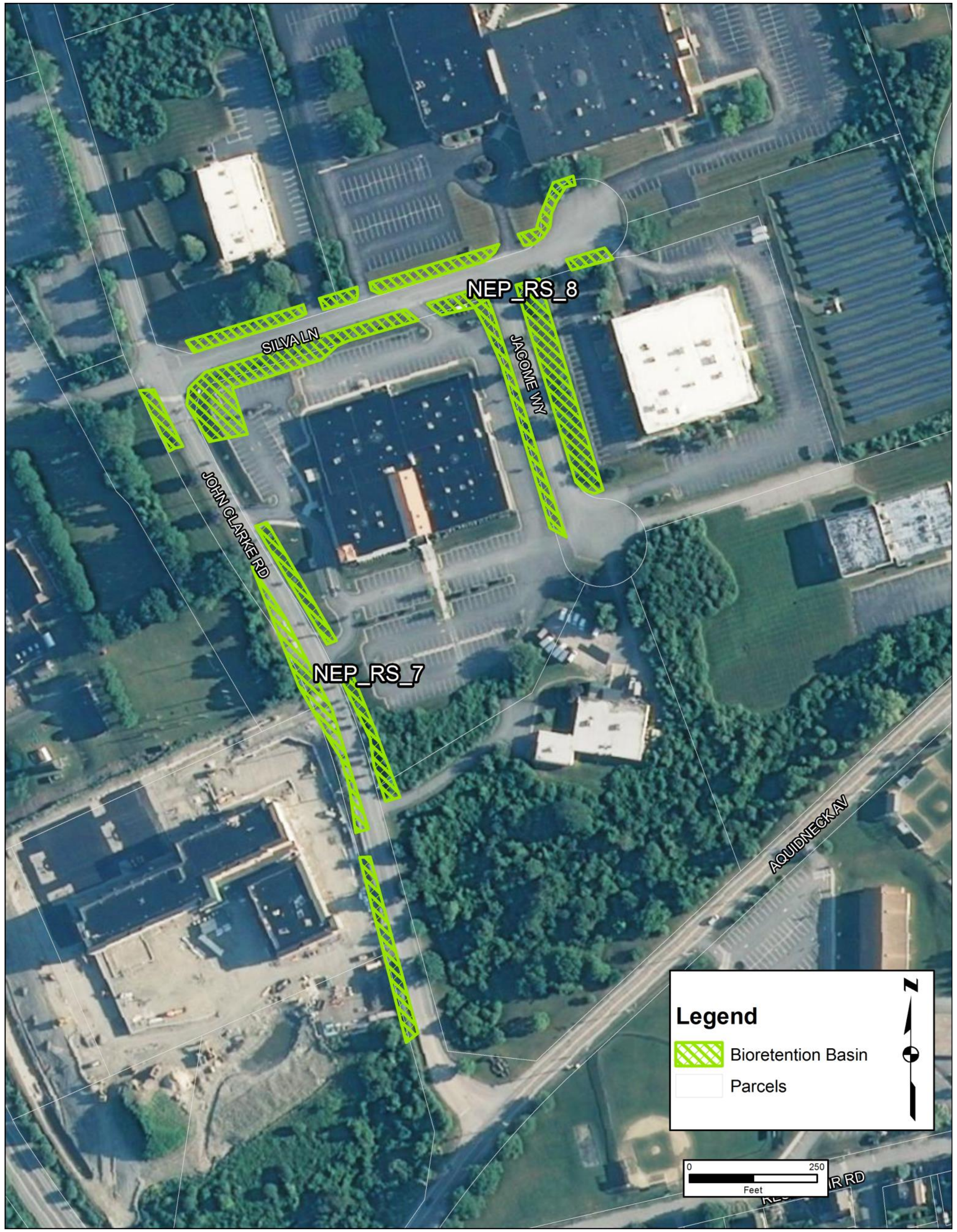


Figure B-11. Bioretention near Silva Ln

Figure B-12. Bioretention at High St and Adelaide Ave

Appendix C

Prioritization Tool Calculations

The Prioritization Tool developed for the **Island Waters** project utilizes a weighted scoring method to reflect the suitability of a particular best management practice (BMP). The tool utilizes both BMP and watershed characteristics, professional judgement a stakeholder input. This appendix outlines the calculation methods used in the Prioritization Tool.

Prioritization Tool Metrics

Prior water quality studies and local initiative on Aquidneck Island identify 90 BMPs across the three municipalities. These BMPs are diverse and specific to the local conditions in which they would be constructed. The Prioritization Tool is designed to consider previously identified BMPs, rather than recommending new BMP locations.

Each previously identified BMP receives a score for their anticipated performance in relation to metrics that are divided into three categories: BMP metrics (which describe characteristics of the individual BMP), watershed metrics (which describe characteristics of the watershed in which the BMP is located), and community metrics (which address the BMP within the context of the local community). Description of the BMP metrics and the rationale for scoring categories is provided Tables C.1, C.2, and C.3.

Metric Weighting

Each metric receives a weight, or contribution, to the category score. This weight is assigned by the user. Assignment of weights and can be based on user judgement or stakeholder input. The higher the weight, the greater the relative influence of a particular metric to a category score. All metrics are given a weight of one (1) by default, reflecting equal input from each metric in a category as a starting point. A metric's score is the product of the weight and a coded numeric response associated with the possible values of that metric. For any single metric *j*, the score is calculated as:

$$b_i = c_{i,j} \times w_j$$

where:
$b_{i,j}$ = the score of the i-th BMP
$c_{i,j}$ = the coded numeric response for the j-th metric for the i-th BMP
w_j = the weight assigned to metric j

For example, for the metric that assesses the hydrologic connection of a BMP to a drinking water supply the possible responses "no connection," "indirect connection," and "direct connection" are associated with the numeric response (0, 1, and 2, respectively). While the numeric response depends on the metric, for all metrics included in this tool, a larger number reflects a more effective BMP. If water supply connection is determined to be an important consideration, the metric might receive a weight of 2.5. Therefore, using the formula above a BMP that flows directly to a water supply would receive a score of 5 for that metric. For example, Figure C.1 shows the weight assigned to the "Drinking Water Supply" metric for five (5) different BMPs, each with a row in the table. The user input for BMPs in rows 1, 3, and 5 corresponded to an input score of 2. When the weight is applied, the weighted score becomes 4. Other BMPs has input scores of 1 and 3, leading to weighted scores of 2 and 6, respectively.

Drinking Water Supply	Weight	Score
Hydrologic connection via a stream or other water body	2.00	4
No hydrologic connection to drinking water supply	2.00	2
Hydrologic connection via a stream or other water body	2.00	4
Direct drainage to a drinking water supply	2.00	6
Hydrologic connection via a stream or other water body	2.00	4

Figure C.1: Example Score Calculations

Calculating the Category Score

The category score for each BMP, which takes into account the weighted metric scores for each of the three metric types, is the sum of all metric scores within that category:

$$C_i = \sum_{i=1}^{n_k} b_i$$

where:

C_i = the category raw score for the i-th BMP

n_k = the number of metrics in the k-th category (here $k = 3$, because there are 3 categories of metrics)

b_i = the BMP score of the i-th BMP for an individual metric

metrics

BMPs

Sum of scores in this row

Educational Opportunity	Weight	Score	Community Acceptance	Weight	Score	Public Visibility	Weight	Score	Conservation Benefits	Weight	Score	Category Score
No Opportunity	1	0	Ambivalence	2	0	No Opportunity	1	0	Some Opportunity	1	1	1.00
No Opportunity	1	0	Ambivalence	2	0	No Opportunity	1	0	Some Opportunity	1	1	1.00
No Opportunity	1	0	Ambivalence	2	0	No Opportunity	1	0	Some Opportunity	1	1	1.00
No Opportunity	1	0	Ambivalence	2	0	No Opportunity	1	0	Some Opportunity	1	1	1.00
Some Opportunity	1	1	Acceptance	2	2	Significant Opportunity	1	2	No Opportunity	1	0	5.00
Some Opportunity	1	1	Acceptance	2	2	Significant Opportunity	1	2	No Opportunity	1	0	5.00

Figure C.2: Example Category Score Calculation in the Community Category.

After all BMPs have received scores in a particular category (i.e., BMP, watershed, or community), those scores are normalized to a 0-10 range. This step equalizes the influence of categories independent of the number of metrics each contains, providing each BMP a score between 0 and 10 for each of the three categories, proportional to its score between the minimum and maximum category score:

$$S_i = \frac{C_j - \min(C)}{\max(C) - \min(C)} \times 10$$

Where, for a particular category:

S_i = the normalized category score (0-10) for the i-th BMP

C_i = the category score for the i-th BMP

C = the set of scores in that category for all BMPs

Calculating the Total Score

The raw total score is sum of standardized scores across all categories.

$$R_i = \sum_{1}^{k} S_i$$

where:

R_i = the total raw score of the i-th BMP

k = the number of categories (here k = 3 because there are 3 categories of metrics)

S_i = the category score (0-10) of the i-th BMP

For ease of comparison, the raw total scores are also normalized to a 0 – 10 scale, proportional to their value between the minimum and maximum total scores:

$$T_i = \frac{R_i - \min(R)}{\max(R) - \min(R)}$$

where:

T_i = the normalized total score (0-10) of the i-th BMP

R_i = the raw total score of the i-th BMP

R = the set of raw total scores for all BMPs

Additional Adjustments

Because the Prioritization Tool is intended as a decision support tool, one of its key features is its flexibility. The tool allows for further adjustments to BMP category and total scores. If, for example, watershed metrics are deemed especially important, additional weight can be applied to that total category score. Further, if additional circumstances exist that are not addressed in the metrics, an additional weighting factor can be applied to the total score. Caution is warranted with these adjustments, which should be used sparingly, if at all, because they have the potential to unduly influence the Tool's prioritization rankings.

Table C.1: Description of BMP Metrics

BMP Metric	Metric Description	Source
Capital Costs	What are the relative costs to design and construction the BMP or a BMP of this type in the location proposed? Different types of BMPs have different capital costs for design and construction which will depend on both BMP type and size. While costs can vary regionally, typical costs per BMP can be divided into 3 ranges. For this Aquidneck Island Waters Project, the cost categories are: 1 = >$100,000/BMP – High Cost 2 = $50,000 - $100,000/BMP – Moderate Cost 3 = <$50,000/BMP – Low Cost	Nation-wide estimates of BMP costs can be found at: Preliminary Data Summary of Urban Storm Water Best Management Practices (EPA-821-R-99-012), August 1999 Regional (New England) Estimates of BMP costs can be found at: Rhode Island Stormwater Desgin and Installation Manual (RIDEM & CRMC, 2015) Optimal Stormwater Management Plan Alternatives: A Demonstration Project in Three Upper Charles in Three Upper Charles River Communities River Communities, December 2009. Other Sources: Costs of Stormwater Management Practices In Maryland Counties prepared for Maryland Department of the Environment by Dennis King and Patrick Hagan of the University of Maryland, Center for Environmental Science (UMCES)
Operation and Maintenance	What is the relative burden of operation and maintenance? BMPs typically require maintenance in order to function effectively. The intensity and frequency of operation and maintenance activities can increase the life cylce cost of BMPs and should be considered during BMP selection in order to account for maintenance cost necessary to assure proper function. Consultation with local engineers and Public Works Departments may lead to adjustment of these cost categories based on local knowledge of regional costs. Based on the work of Houle et al. (2013), the annual cost categories are: 1= <$1,000/yr - Low burden 2= $2,000 - $5,000/yr - Moderate burden 3= >$5,000/yr - High burden.	Regional (New England) estimates of maintenance costs include: Comparison of Maintenance Cost, Labor Demands, and System Performance for LID and Conventional Stormwater Management (Houle et al., 2013) Rhode Island Stormwater Desgin and Installation Manual (RIDEM & CRMC, 2015) Other Sources: Costs of Stormwater Management Practices In Maryland Counties prepared for Maryland Department of the Environment by Dennis King and Patrick Hagan of the University of Maryland, Center for Environmental Science (UMCES) Stormwater Best Management Practices Greater Baltimore Survey 2016 (Klein, 2016)
Sensitivity to O&M	How sensitive to routine/recommended O&M is the performance of the BMP? After installation, BMPs can suffer from under-maintenace or lack of maintenance all together which can lead to insufficient function or failure of the BMP. Therefore understanding and communicating the sensitivity of the BMP to maintenance requirements is critical for long term function. While sensitivity to maintenance will , in part, be a function of the particular BMP location and the characterisitics (especially sediment load) of the stormwater treated by the BMP, the following sensitivity categories are used for the Aquidneck Island Waters Project: 1 – Requires maintenance more than 1x/yr – Very Sensitive 2 – Requires maintenance 1x/yr – Moderately Sensitive 3 – Requires maintenance once every few years – Slightly Sensitive	Rhode Island Stormwater Desgin and Installation Manual (RIDEM & CRMC, 2015) Other Sources: Costs of Stormwater Management Practices In Maryland Counties prepared for Maryland Department of the Environment by Dennis King and Patrick Hagan of the University of Maryland, Center for Environmental Science (UMCES) Stormwater Best Management Practices Greater Baltimore Survey 2016 (Klein, 2016)

BMP Metric	Metric Description	Source
Permitting Complexity	Will the BMP require permits at multiple levels of government that increase the complexity of the permitting process? Stormwater BMPs must undergo a permitting process by local, state, and/or, federal government entities. Site-specific factors that may trigger review by various agencies can increase the level of effort required to successfully apply for a permit, and/or increase the duration of the permitting process, potentially making a BMP less appealing. Examples of challenges that may increase permitting difficulty may include projects that alter the hydrology of a wetland or are located within a wetland or regulatory floodway. 1 = Low complexity. Local permitting only 2 = Moderate complexity. Local and state permitting required 3 = High complexity. Significant state and/or federal permitting required	
Scale of Practice	What amount of area is the BMP anticipated to treat? Individual BMPs treat the water coming from an area of a given size. The more area a BMP is expected to treat, the more effective it can be at reducing the impact of stormwater runoff pollution. This category does not cover the capability of the BMP to treat the water quality volume. 1 = Less than 1 acre 2 = Between 1-5 acres 3 = Greater than 5 acres	
Bacteria Removal Capability	What is the potential relative bacteria removal capability of the BMP? Pollutant removal efficiency, usually represented by a percentage removal, specifically refers to the pollutant reduction from the inflow to the outflow of a system. Different types of BMPs have different capabilities for removing different types of pollutants and over the life of a BMP removal efficiency will depend on several factors including maintenance. The ranking used here describes pollutant removal capacity for a properly functioning BMP. In Rhode Island, structural BMPs are generally required to achieve the following minimum average pollutant removal efficiencies: 85% removal of total suspended solids (TSS), 60% removal of pathogens, 30% removal of total phosphorus (TP) for discharges to freshwater systems, and 30% removal of total nitrogen (TN) for discharges to saltwater or tidal systems. For the Aquidneck Island Waters Project, the Rhode Island Stormwater Design and Installation Manual (RIDEM & CRMC, 2015), is used for the following scores of removal efficiency: 1 = Low 2 = Moderate 3 = High For other geographies, the sources listed can be consulted for removal efficiency information.	Rhode Island Stormwater Desgin and Installation Manual (RIDEM & CRMC, 2015) National Pollutant Removal Performance Database Version 3 (Center for Watershed Protection, 2007) University of New Hampshire Stormwater Center, 2009 Biannual Report The Illinois Green Infrastructure Report (Jaffe et al., 2010)

BMP Metric	Metric Description	Source
Nutrient Removal Capability	What is the potential relative bacteria removal capability of the BMP? Pollutant removal efficiency, usually represented by a percentage removal, specifically refers to the pollutant reduction from the inflow to the outflow of a system. Different types of BMPs have different capabilities for removing different types of pollutants and over the life of a BMP removal efficiency will depend on several factors including maintenance. The ranking used here describes pollutant removal capacity for a properly functioning BMP. In Rhode Island, structural BMPs are generally required to achieve the following minimum average pollutant removal efficiencies: 85% removal of total suspended solids (TSS), 60% removal of pathogens, 30% removal of total phosphorus (TP) for discharges to freshwater systems, and 30% removal of total nitrogen (TN) for discharges to saltwater or tidal systems. For the Aquidneck Island Waters Project, the Rhode Island Stormwater Design and Installation Manual (RIDEM & CRMC, 2015), is used for the following scores of removal efficiency: 1 = Low 2 = Moderate 3 = High For other geographies, the sources listed can be consulted for removal efficiency information.	Rhode Island Stormwater Desgin and Installation Manual (RIDEM & CRMC, 2015) National Pollutant Removal Performance Database Version 3 (Center for Watershed Protection, 2007) University of New Hampshire Stormwater Center, 2009 Biannual Report The Illinois Green Infrastructure Report (Jaffe et al., 2010)
Sediment Removal Capability	What is the potential relative bacteria removal capability of the BMP? Pollutant removal efficiency, usually represented by a percentage removal, specifically refers to the pollutant reduction from the inflow to the outflow of a system. Different types of BMPs have different capabilities for removing different types of pollutants and over the life of a BMP removal efficiency will depend on several factors including maintenance. The ranking used here describes pollutant removal capacity for a properly functioning BMP. In Rhode Island, structural BMPs are generally required to achieve the following minimum average pollutant removal efficiencies: 85% removal of total suspended solids (TSS), 60% removal of pathogens, 30% removal of total phosphorus (TP) for discharges to freshwater systems, and 30% removal of total nitrogen (TN) for discharges to saltwater or tidal systems. For the Aquidneck Island Waters Project, the Rhode Island Stormwater Design and Installation Manual (RIDEM & CRMC, 2015), is used for the following scores of removal efficiency: 1 = Low 2 = Moderate 3 = High For other geographies, the sources listed can be consulted for removal efficiency information.	Rhode Island Stormwater Desgin and Installation Manual (RIDEM & CRMC, 2015) National Pollutant Removal Performance Database Version 3 (Center for Watershed Protection, 2007) University of New Hampshire Stormwater Center, 2009 Biannual Report The Illinois Green Infrastructure Report (Jaffe et al., 2010)

BMP Metric	Metric Description	Source
Removal Capability of Other Pollutants	What is the potential relative bacteria removal capability of the BMP? Pollutant removal efficiency, usually represented by a percentage removal, specifically refers to the pollutant reduction from the inflow to the outflow of a system. Different types of BMPs have different capabilities for removing different types of pollutants and over the life of a BMP removal efficiency will depend on several factors including maintenance. The ranking used here describes pollutant removal capacity for a properly functioning BMP. In Rhode Island, structural BMPs are generally required to achieve the following minimum average pollutant removal efficiencies: 85% removal of total suspended solids (TSS), 60% removal of pathogens, 30% removal of total phosphorus (TP) for discharges to freshwater systems, and 30% removal of total nitrogen (TN) for discharges to saltwater or tidal systems. For the Aquidneck Island Waters Project, the Rhode Island Stormwater Design and Installation Manual (RIDEM & CRMC, 2015), is used for the following scores of removal efficiency: 1 = Low 2 = Moderate 3 = High For other geographies, the sources listed can be consulted for removal efficiency information.	Rhode Island Stormwater Desgin and Installation Manual (RIDEM & CRMC, 2015) National Pollutant Removal Performance Database Version 3 (Center for Watershed Protection, 2007) University of New Hampshire Stormwater Center, 2009 Biannual Report The Illinois Green Infrastructure Report (Jaffe et al., 2010)
Capable of Treating the Water Quality Volume?	Will the BMP be able to treat the estimated water quality volume? The amount of runoff that must be treated from each rainfall event is known as the required water quality volume (WQv). Site limitations, especially in retrofit situations, can sometimes reduce the amount of stormwater that a BMP may prevent the entire WQv from being treated by a BMP. For example, a lack of available space can require a reduction in the footprint of the BMP that reduces the volume of water that can be treated for a given storm. Because the WQv varies from state to state and may be different for new construction and redevelopment sites, it is important to know the requirements for your area and project type and consult with an engineer to understand the WQv potentially treated by a proposed BMP. For the Aquidneck Island Waters Project, the WQv is equivalent to 1.2” rainfall runoff. 1= <50% of the WQv can be treated – Low Capability 2= 50-90% of the WQv can be treated – Moderate Capability 3= >90% of the WQv can be treated – High Capability	Information on Rhode Island Standards: Rhode Island Stormwater Desgin and Installation Manual (RIDEM & CRMC, 2015) Consult state or local requirements for the WQv required for different geographies.

BMP Metric	Metric Description	Source
Provide Flood Improvements	Will the BMP ameliorate existing flooding conditions? In areas impacted by localized flooding, stormwater BMPs that promote “green infrastructure practices” such as infiltration help to absorb rainfall and can reduce the potential for both localized and riverine flooding. Green infrastructure practices that enhance infiltration include rain gardens, bioswales, and permeable pavements. In Rhode Island, the Rhode Island Stormwater Desgin and Installation Manual indicates BMPs that provide overbank flood control. Additional information on the use of stormwater BMPs to reduce flood risks can be found in the sources. The rating for this metric should be based on existing conditions (i.e., does a flooding situation currently exist?), as well as the capability of the BMP to reduce localized or riverine flooding. 1= Not located in a flood-prone area and/or BMP does not provide infiltration capacity - Low capability 2=Located in a flood-prone area and BMP provides some infiltration capacity - Moderate capability 3= Located in a flood-prone area and BMP provides infiltration capacity - High capability.	Information on the flood control benefits of stormwater BMPs can be found at the following sources: In Rhode Island Rhode Island Stormwater Desgin and Installation Manual (RIDEM & CRMC, 2015) Nationally A Flood of Benefits: Using Green Infrastructure to Reduce Flood Risks (Opperman, 2014) Flood Loss Avoidance Benefits of Green Infrastructure for Stormwater Management (Atkins, 2015) Information on riverine flooding can be found from FEMA Floodplain Mapping. Information on local flooding can be obtained from local stakeholders as well as municipal public works departments and emergency services.
Potential for Nuisance Conditions	Is the BMP prone to nusiance conditions (i.e., mosquitoes, overgrown vegetation, etc) that is incompatible or objectionable with surrounding land use? The design of some BMPs can yield situations that are more prone to development of potential nuisance conditions. For example, BMPs with standing water may cause an increase in mosquitos or cause odors. Those with vegetation may become overgrown if not properly maintained. When BMPs are sited in or near residential or commercial land uses they may be more likely to generate complaints of nuisance conditions. In general, proper design and maintenance is critical to preventing nuisance conditions. The ranking is based on both the location of the BMP (i.e., near locations where neighbors, etc could consider nuisance conditions to exist) and the potential for nuisance conditions (i.e., excessive standing water, over grown vegetation) to exist. 1= Both BMP location and design create potential nuisance conditions - High potential to develop nuisance conditions 2= Either BMP location or design create potential nuisance conditions - Moderate potential 3= Neither BMP location nor design create potential nuisance conditions - Low potential	Description of typical nuisance conditions can be found in: Minnesota Stormwater Manual (Minnesota Pollution Control Agency, 2013)
Resistant to Rising Sea Levels	For BMPs in coastal areas and/or areas of projected SLR within 50 years, is the BMP function resistant to projected SLR? Some BMPs are not designed to withstand saltwater intrusion. Others can be designed to mitigate the impacts of sea level rise, or are not affected by sea level rise by design or are not in an area projected to be impacted by sea level rise. 1=Design cannot be modified to mitigate impacts 2=Design can be modified to mitigate impacts 3=Design does not need modification	Information on projected sea level rise (SLR) in Rhode Island can be found at: RIGIS StormTools Nationally, NOAA’s Digital Coast provides estimates of SLR and storm surge. The US Army Corps of Engineers also provides estimates of SLR. Many coastal states also have projections of sea level rise. NOAA Digital Coast USACE Sea-Level Change Curve Calculator (2015.46)

BMP Metric	Metric Description	Source
Resistant to Rising Ground Water	For BMPs utilizing infiltrations, is the BMP function resistant to rising ground water levels (i.e., decreased separation distance)? BMPs that rely heavily on infiltration for stormwater treatment require a certain separation distance to the groundwater table because infiltration does not occur in soils where groundwater is elevated. This is determined by groundwater depth information and BMP design. Engineering design professionals can provide information about the BMP design. 1=Design relies on infiltration and cannot be modified to deal with a high water table – Not/slightly resistant 2= Design relies on infiltration but can be modified to adapt to resisting water table – Moderately resistant 3=Design does not rely on infiltration and/or would not need modification	Engineering design professionals should be consulted regarding the use of infiltration, the adaptability of the BMP, and the regional ground water elevations.
Resistant to Storm Surge	For BMPs in coastal areas and/or areas of projected SLR within 50 years, is the BMP resistant to storm surge? Wave action can destroy some types of BMPs when placed in an area with the potential for storm surge. Some designs can be modified to reduce the impact of wave action. This is determined by the design of the BMP and its location in a storm surge area 1=Design cannot be modified to mitigate impacts 2=Design can be modified to mitigate impacts 3=Design does not need modification	Sources of information for New England on siting BMPs in coastal areas include: Assessment of Climate Change Impacts on Stormwater BMPs and Recommended BMP Design Considerations in Coastal Communities (Horsley Witten Group, 2015) Information on flood zone and storm surge elevations are available from state agencies responsible for coastal zone management. In Rhode Island, information can be found at: RIGIS FEMA DFIRM RIGIS StormTools Nationally, NOAA's Digital Coast provides estimates of storm surge. NOAA Digital Coast
Resistant to Wetter Conditions	Will the BMP function as intended under exposure to more frequent, higher intensity rainfall events? Will the BMP be able to adapt to wetter conditions anticipated for New England? Generally, vegetated BMPS are better able to accommodate this than more traditional "grey" infrastructure. For example, a surface infiltration basin could convert over time to a wet basin as groundwater rises, the timing and frequency of rainfall changes, and conditions become wetter overall. 1 = BMP is a grey infrastructure approach that is less able to adapt to wetter conditions and may not be able to perform as expected under more frequent, higher intensity storms – Not/slightly Resistant 2 = BMP is a vegetated approach that is somewhat able to adapt to wetter conditions and may likely be able to perform as expected under more frequent, higher intensity storms – Moderately Resistant 3 = BMP is a vegetated approach that is designed to be able to adapt to wetter conditions and perform as expected under more frequent, higher intensity storms – BMP is a vegetated approach that is somewhat able to adapt to wetter conditions and may likely be able to perform as expected under more frequent, higher intensity storms – Very Resistant	A study funded by the Massachusetts Office of Coastal Zone Management provides information on design considerations for BMPs in coastal communities under climate change: Assessment of Climate Change Impacts on Stormwater BMPs and Recommended BMP Design Considerations in Coastal Communities

BMP Metric	Metric Description	Source
Resistant to Chronic Wind, Sand, Salt	For BMPs in coastal areas and/or areas of projected SLR within 50 years, will the BMP function as intended under exposure to wind, salt, and sand? For BMPs located on the coast, appropriate salt-tolerant plant species and materials that do not corrode from salt exposure will be more sustainable and perform better under conditions or current or future chronic exposure to wind, sand, and salt spray. 1 = BMP is located in a current or potential future area of exposure and is susceptible to impacts from chronic wind, sand or salt spray – Not/slightly Resistant 2 = BMP is located in a current or potential future area of exposure but is designed to provide some resistance to impacts from chronic wind, sand or salt spray – Moderately Resistant 3 = BMP is not located in an area of current or potential future exposure, or is located in a current or potential future area of exposure but is designed to provide robust resistance to impacts from chronic wind, sand or salt spray – Very Resistant	A study funded by the Massachusetts Office of Coastal Zone Management provides information on design considerations for BMPs in coastal communities under climate change: Assessment of Climate Change Impacts on Stormwater BMPs and Recommended BMP Design Considerations in Coastal Communities

Table C.2: Description of Watershed Metrics

Watershed Metric	Metric description	Source
Ownership	What is the ownership of the parcel where the BMP will be sited? Current ownership of the parcel that is the location of the proposed BMP is determined by review of local mapping. Presence of conservation or other easements and ownership of those easements is also considered. In general, land already publicly-owned, owned by a non-governmental organization actively involved in conservation, or with an easement held by a governmental or conservation agency will be a better candidate for BMP construction. Privately owned parcels may be more challenging to gain permission for construction of a BMP and maintenance responsibilities would need to be clearly defined. As a result, publically-owned sites are highest scoring, followed by privately-owned sites with easements. Privately-owned sites are the lowest scoring. 1 = Privately Owned 2 = Privately-owned with easement 3 = Publically-owned	Town Parcel GIS Database or Tax Assessors Data
Drinking Water Supply	Does the BMP discharge to a public drinking water supply or its tributaries? Stormwater flows to and replenishes groundwater or surface water supplies. When these supplies are used for drinking water, stormwater can act as both a source of drinking water and a source of pollution. The hydrologic connection of stormwater BMPs to surrounding water bodies or groundwater is determined by field observations and topographic GIS mapping. Additionally, different types of BMPs have variable design capabilities to remove pollutants such as nutrients, bacteria, and metals from a certain calculated amount of stormwater. These design criteria should be considered when siting a BMP. If it drains to a public drinking water supply or its tributary, the BMP can help reduce the pollutant load that enters drinking water reservoirs. This decreases the amount of treatment that must occur within the drinking water system. 0=BMP is not hydrologically connected to a drinking water supply 1=BMP is hydrologically connected via a stream or other connecting water body 3=BMP drains directly into a drinking water supply	In RI, information on drinking water supply regulatory setbacks for stormwater BMPs can be found in: RI Stormwater Design Manual (RIDEM & CRMC 2015) GIS data on drinking water supply protection areas, topography, and surface waters are available from RIGIS: Surface water protection areas Community protection areas Non-community protection areas Groundwater recharge areas Topographic information Lakes Streams
Public Bathing Beach	Does the BMP discharge to the waters or tributaries of a public bathing beach? Stormwater can transport pollutants such as bacteria to bathing waters downstream. Public beaches and waters that allow primary contact recreation, or activities that involve a significant probability of water ingestion, are often closed following large storm events due to an unsafe concentration of pathogenic bacteria . The hydrologic connection of BMPs to public bathing waters is determined by field observations and GIS mapping. Additionally, different types of BMPs have variable design capabilities to remove bacteria from a certain calculated amount of stormwater. These design criteria should be considered when siting a BMP. If it drains to the water of a public bathing beach or its tributary, the BMP can help decrease the pollutant load following a storm. This can help reduce the number of days that a public bathing beach is closed by the Department of Health. 0=BMP is not hydrologically connected 1=BMP is hydrologically connected via a stream or other connecting water body 3=BMP drains directly into a public bathing beach	In RI, the waters of public beaches are monitored by the RI Dept. of Health, which maintains publically available closure data. RI Public Beach Closure Data RI Topography RI Lakes RI Streams In MA, the Dept. of Conservation and Recreation and the Dept. of Public Health monitor bathing water safety. MA Public Beach Closure Data MA Topography MA Hydrography Similar testing programs and data exist for other states in the region.

Watershed Metric	Metric description	Source
Shellfishing Area	Does the BMP discharge to a shellfishing area or its tributaries? Stormwater can transport pollutants such as bacteria to shellfishing grounds downstream. Shellfish eat by filtering particles from their surroundings. In waters that receive polluted stormwater, these particles can contain high concentrations of pathogenic bacteria. Consumption of contaminated shellfish can cause illness so these areas are typically closed to shellfishing or subject to harvesting conditions and closures. The hydrologic connection of BMPs to shellfishing grounds is determined by field observations and GIS mapping. Additionally, different types of BMPs have variable design capabilities to remove bacteria from a certain calculated amount of stormwater. These design criteria should be considered when siting a BMP. If it drains to a shellfishing ground or its tributary, the BMP can help reduce the pollutant load following a storm. This can help increase the area where shellfish can be safely harvested. 0=BMP is not hydrologically connected 1=BMP is hydrologically connected via a stream or other connecting water body 3=BMP drains directly into the shellfishing waters	RI shellfish harvesting restriction data RI Topography RI Lakes RI Streams MA shellfish harvesting restriction data MA Topography MA Hydrography
Imperviousness	How much impervious cover exists in the watershed? Rainfall on impervious cover (IC) runs off immediately to stormwater infrastructure and carries with it pollutants on the surface or in catchbasins. Increases in IC mean an increase in stormwater runoff and associated pollutants. This increase in runoff heightens flood risk and worsens streambank erosion, altering stream morphology. This erosion increases the sediment load of a stream, which settles on and suffocates benthic habitat. Previous studies have shown that beyond 10% IC in a watershed, streams start to show signs of impairment due to reduced water quality. Beyond 25% IC, the stream is considered severely impacted and effectively acts only as a stormwater conduit. Stormwater BMPs disconnect IC from itself, reducing its impact on water quality and flood risk by increasing stormwater infiltration or detention or by providing water quality treatment. 1= Less than 10% IC 2= 10-25% IC 3= Greater than 25% IC	The Need to Reduce Impervious Cover to Prevent Flooding and Protect Water Quality (RIDEM, 2010) The Importance of Imperviousness (Schueler 1994) http://scc.wa.gov/wp-content/uploads/2015/06/The-Importance-of-Imperviousness_Schueler_2000.pdf Nationally, an EPA annotated bibliography of studies examining the link between watershed imperviousness, water quality, and biological integrity. https://www.epa.gov/sites/production/files/2015-11/documents/rp2wshedimperv1109.pdf
Impaired Waters	Does the BMP discharge to an Impaired Water or its tributary? Section 303d of the Clean Water Act requires that states identify waters that do and do not meet designated use criteria, such as supporting drinking water, bathing, fishing/boating, aquatic life, and irrigation. States must then take steps to reduce the level of the pollutant identified as causing the impairment to those uses. Stormwater can be a vector by which pollutants are transported to impaired waters. The hydrologic connection of BMPs to impaired waters is determined by field observations and GIS mapping. Additionally, different types of BMPs have variable design capabilities to remove pollutants such as nutrients, bacteria, and metals from a certain calculated amount of stormwater. These design criteria should be considered when siting a BMP. If it drains to an impaired water body or its tributary, the BMP can help reduce the pollutant load and contribute to removing the Impaired designation. 0=does not drain to an impaired water 3=drains to an impaired water.	RI Impaired Waters List (2014) RI Integrated Water Quality Monitoring and Assessment Report (2012) MA Impaired Waters List (2016) MA Integrated Water Quality Monitoring and Assessment Report (2012) Other states maintain similar lists, but data products may be variably available.
Habitat Benefit	Does the BMP provide ancillary habitat benefit? The design or nature of some BMPs includes vegetation or creates wetland or other habitat area (e.g. riparian zone restoration or constructed wetland). Designs that incorporate native vegetation may be the most effective at creating ecologically relevant habitat. These provide a secondary benefit to watershed health beyond stormwater management and flood control. 0=design does not include habitat 1=design includes habitat	Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring (US FHWA)

Watershed Metric	**Metric description**	**Source**
Primary Land Use Loading - Pollutant of Concern	In the watershed, is the dominant land use a significant contributor of the pollutant of concern? Non-point source pollution enters water bodies via stormwater runoff. It is challenging to determine the exact location of its source because it is distributed across the watershed. The specific pollutants that are picked up by runoff depend on the land use that the runoff encountered. Residential land uses may be greater sources of nutrients and bacteria (e.g. from lawn fertilizer and septic systems) than industrial land uses. Agricultural land uses may generate higher nutrient loads than commercial land uses. The relative proportion of land uses in a watershed impacts the amount of a pollutant available to be picked up by runoff from a watershed and directly influences stormwater quality. Compared to an undeveloped (e.g. forested or similarly undisturbed) watershed, the most prevalent land use in the watershed is a: 1=Low source of the pollutant of concern 2=Medium source of the pollutant of concern 3=High source of the pollutant of concern	Land Use & Water Quality (Purdue University Extension) Land Use Loading Rate Literature Review RI land use data Other states may have similar land use or land cover data products publically available
Secondary Land Use Loading - Pollutant of Concern	In the watershed, is the second-most dominant land use a significant contributor of the pollutant of concern? Non-point source pollution enters water bodies via stormwater runoff. It is challenging to determine the exact location of its source because it is distributed across the watershed. The specific pollutants that are picked up by runoff depend on the land use that the runoff encountered. Residential land uses may be greater sources of nutrients and bacteria (e.g. from lawn fertilizer and septic systems) than industrial land uses. Agricultural land uses may generate higher nutrient loads than commercial land uses. The relative proportion of land uses in a watershed impacts the amount of a pollutant available to be picked up by runoff from a watershed and directly influences stormwater quality. Compared to an undeveloped (e.g. forested or similarly undisturbed) watershed, the most prevalent land use in the watershed is a: 1=Low source of the pollutant of concern 2=Medium source of the pollutant of concern 3=High source of the pollutant of concern	Land Use & Water Quality (Purdue University Extension) Land Use Loading Rate Literature Review RI land use data Other states may have similar land use or land cover data products publically available

Table C.3: Description of Community Metrics

Community Metric	Metric Description	Source
Educational Opportunity	Is there an opportunity for the BMP to provide public education – either through passive education (such as interpretive signage) or active education (such as citizen science or other participatory programs)? Both the BMP type and location may influence the opportunities for public education. For example, a BMP installed along a recreational path may be seen by many visitors on an annual basis or a BMP installed at a school or public building may allow for vegetation monitoring or water quality sampling as part of classroom, club, or community service projects. 0 = Due to BMP type and/or location there is no opportunity for public education – No Opportunity 1 = Due to BMP type and/or location there is some opportunity for public education – Some Opportunity 2 = Due to BMP type and/or location there is significant opportunity for public education – Significant Opportunity	Examples of passive and active education opportunities with BMPs can be found in the following sources: Passive: Capital Region Watershed District, Green Infrastructure Signage, St. Paul, MN Columbia Heights Library BMP Showcase, Columbia Heights, MN Active: Citizen Science at the Monterey Bay National Marine Sanctuary, Monterey Bay, CA Passive and Active: Villanova Bio-Infiltration Traffic Island, Villanova, PA A Citizen's Guide to Maintaining Stomwater Best Management Practices
Community Acceptance	Is the BMP likely to be accepted into the neighborhood – whether residential, commercial, or rural – or will it meet with opposition in the planning, permitting, and construction phases? -1 = Neighbors are likely to actively oppose the BMP in the public permitting process and speak out against the project – Opposition Likely 0 = Neighbors appear to have little interest in the project as long as it does not directly involve their property – Ambivalence 1 = Some neighbors have expressed an interest and endorsement of the project – Slight Acceptance 2 = Several neighbors have expressed an interest and endorsement of the project either in writing, attendance at meetings, or speaking with project proponents – Moderate Acceptance 3 = Many neighbors or an organized neighborhood group(s) have expressed interest, support, and endorsement of the project either in writing, attendance at meetings, or speaking with project proponents and have expressed an interest to be involved in the project – Enthusiastic Acceptance	Information on Community Acceptance of stormwater BMPs can be found at: Community Acceptance of Stormwater BMPs (Kansas City Water Services, 2014) Wagner, Mimi M. "Acceptance by knowing? The social context of urban riparian buffers as a stormwater best management practice." Society and Natural Resources 21.10 (2008): 908-920. Armstrong, Andrea, and Richard C. Stedman. "Landowner willingness to implement riparian buffers in a transitioning watershed." Landscape and Urban Planning 105.3 (2012): 211-220. Local organizations and municipal officials can provide insight into potential community acceptance of BMPs and also be helpful in building understanding and acceptance.
Public Visibility	Is the BMP located in an area of where members of the public will be able to both see the BMP and gain some understanding of how it works and what water quality issues it addresses? 0 = The BMP is neither located in an area where the public will see it nor is there any opportunity for the public to understand how the BMP relates to water quality – No Opportunity 1 = The BMP is either located in an area where the public will see it or there is an opportunity for the public to understand how the BMP relates to water quality – Some Opportunity 2 = The BMP is both located in an area where the public will see it and there is opportunity for the public to understand how the BMP relates to water quality – Significant Opportunity	Local stakeholders can provide information on public access to the proposed BMP site and the potential for signs or other tools for awareness.

Community Metric	Metric Description	Source
Conservation Benefits	Are there opportunities for other conservation benefits, like preserving natural areas (e.g., buffer protection) or providing water conservation (e.g. a cistern can provide potential for rainwater reuse)? The type and location of BMPs will influence potential conservation benefits. 0 = Given the location or type of BMP proposed, there is no additional opportunity for conservation benefits – No Opportunity. 1 = Given the location or type of BMP proposed, there is the potential for some type of additional conservation benefits – Some Opportunity 2= Given the location or type of BMP proposed, there is the potential for multiple conservation benefits – Significant Opportunity	

Appendix D

Conceptual BMP Designs

Figure 1 – Filter Berm & Bioreactor Locations (Tibbets Farm, Middletown, RI)

Proposed Concept: Install nitrate bioreactors and filter berms along the southern edge of two fields on Plats/Lots 118-31 and 123-700. These practices would filter and treat runoff from agricultural fields in the headwater area of the Maidford River. The denitrifying bioreactors would treat shallow groundwater. On the surface, an additional filter berm would be constructed at each location to temporarily pond water and filter runoff before it reaches the headwaters of the Maidford River. Filter berms primarily treat phosphorus, including phosphorus travelling with soil particles.

Estimated Load Reduction

<u>Filter Berm</u>
Total Nitrogen: 40%
Total Phosphorus: 50%
Total Suspended Solids: 58%

<u>Bioreactor</u>
Total Nitrogen: 90%
Total Phosphorus: N/A
Total Suspended Solids: N/A

Estimated Cost
$120,000

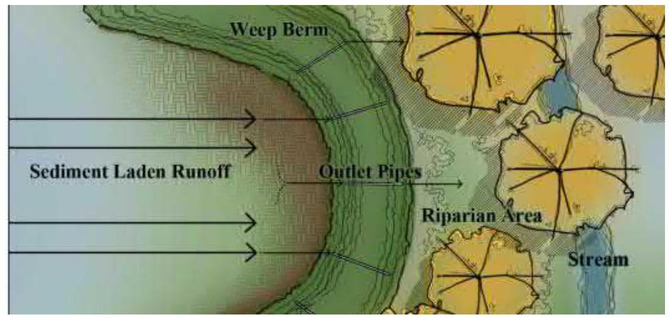
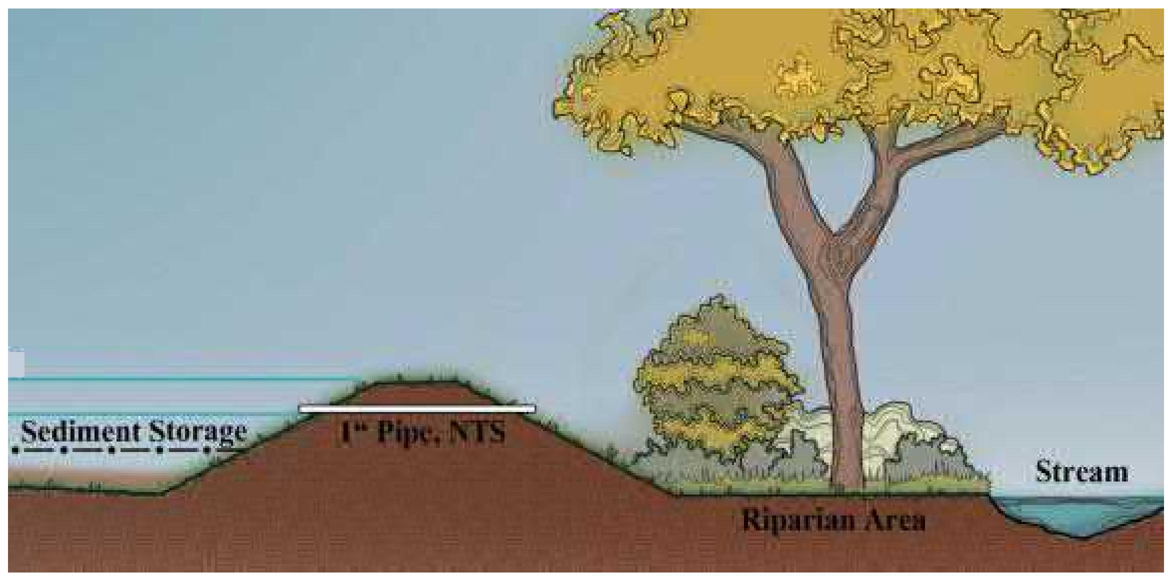


Figure 2 – Plan View of Filter Berm (left)
Figure 3 – Profile of Filter Berm (bottom)
(Source: Warner et al., 2012)

Figure 4 – Filter Berm (Source: Guffy, 2012)



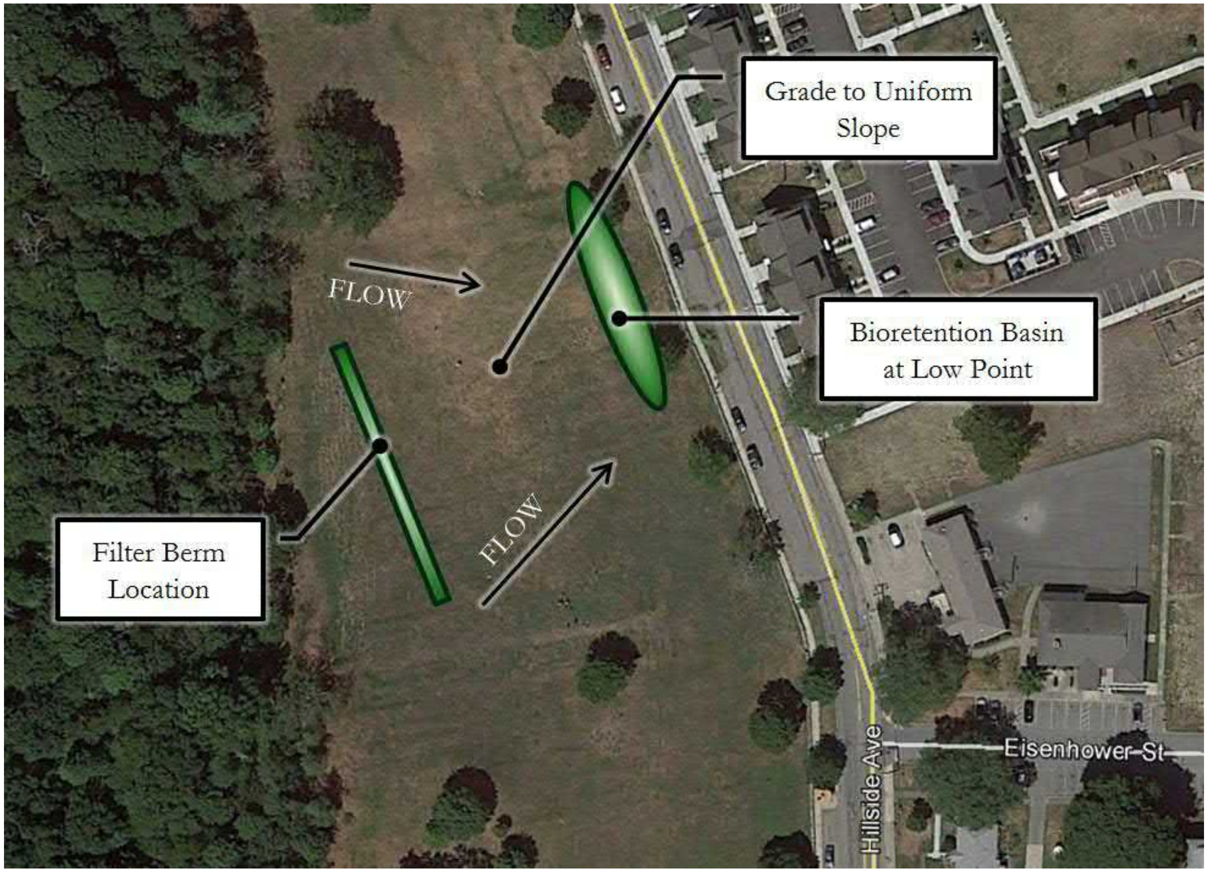


Figure 1 (above) – Filter Berm & Bioretention Basin Locations (Miantonomi Park, Newport, RI)

Proposed Concept: Construct a filter berm and bioretention basin. The new filter berm and bioretention basin will improve existing conditions by managing and treating runoff. The filter berm will collect runoff from upland areas and evenly distribute it to uniformly flow over the playing fields. The new bioretention basin will be at the localized low-point of the area and collect runoff from the playing field. In addition to managing runoff, these measures will also treat for Total Suspended Solids, Total Nitrogen, and Total Phosphorus.

Estimated Load Reduction

Filter Berm

Total Nitrogen: 40%
Total Phosphorus: 50%
Total Suspended Solids: 60%

Bioretention Measure

Total Nitrogen: 55%
Total Phosphorus: 30%
Total Suspended Solids: 90%

Estimated Cost
$120,000

Figure 2 – View of Miantonomi Park from Hillside Avenue

Figure 1 –Typical WVTS after Planting

Figure 2 – Typical WVTS after Plant Growth

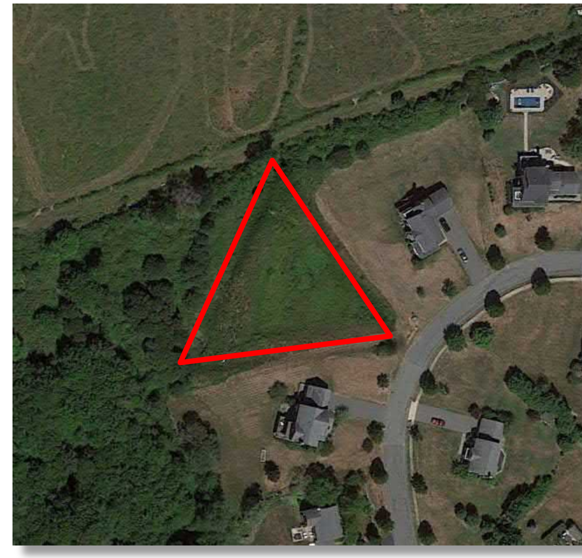


Figure 3 – WVTS Location
(Island Drive, Middletown, RI)

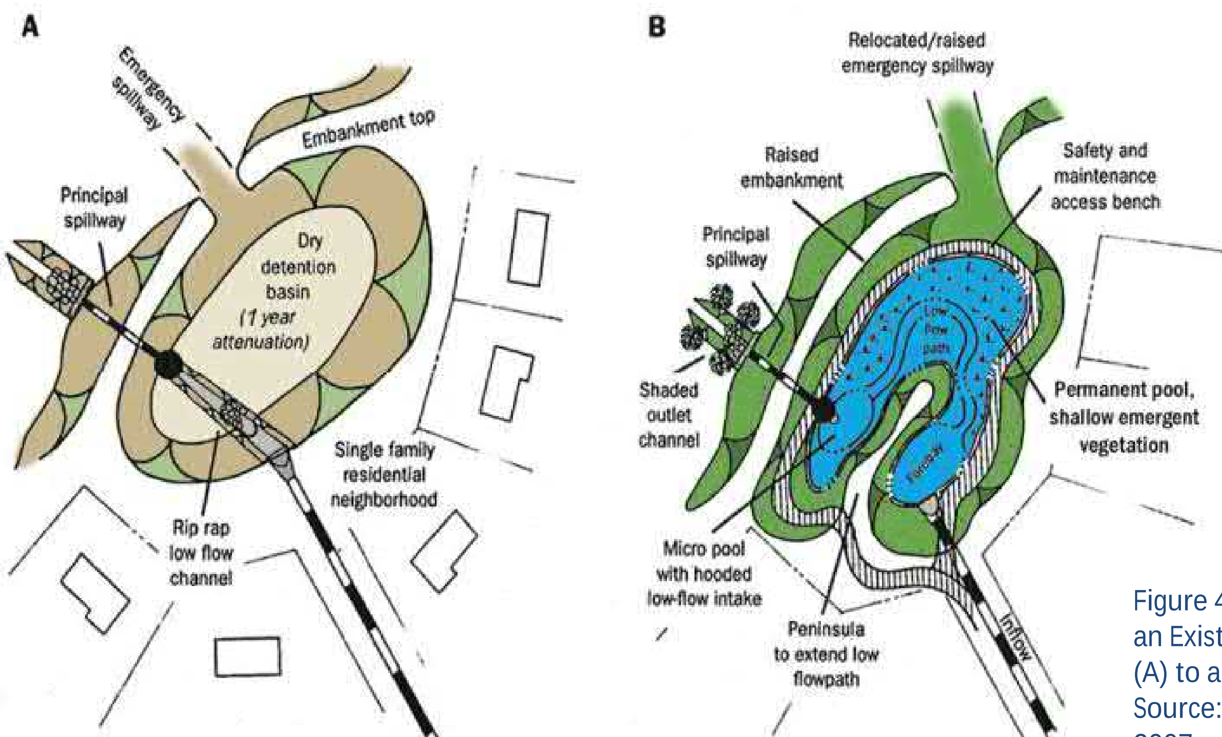


Figure 4 (right) –Retrofit of an Existing Detention Basin (A) to a Shallow WVTS (B) Source: Adopted from CWP, 2007

Proposed Concept: Retrofit the existing stormwater basin to function as a Wet Vegetated Treatment System (WVTS). WVTSs are most appropriate due to the likelihood of high groundwater in the area.

WVTSs are typically wet stormwater basins that provide water quality treatment primarily in a shallow vegetated permanent pool or wet gravel bed with emergent vegetation. Plantings that are part of the WVTS can also provide habitat benefits.

Estimated Pollutant Removal
Total Phosphorus ≈ 48%
Total Nitrogen ≈ 30%
Total Suspended Solids ≈ 85%

Estimated Cost
$210,000

Figure 1 (above) – Vegetative Buffer & Bioretention Basin Locations (Spouting Rock Drive, Newport, RI)

Estimated Pollutant Removal

Bioretention Basin	Vegetated Buffer
Total Phosphorus ≈ 30%	Total Phosphorus ≈ 40%
Total Nitrogen ≈ 55%	Total Nitrogen ≈ 50%
Total Suspended Solids ≈ 90%	Total Suspended Solids ≈ 75%

Estimated Cost
$240,000

Proposed Concept: Remove a portion of the existing pavement and construct a vegetative buffer and a bioretention basin. The existing pavement includes the eastern side of Spouting Rock Drive and a portion of the northern side. The proposed vegetated or riparian buffer will comprise an area of trees and shrubs that can help intercept nutrients, sediments, pesticides, and other pollutants in surface and shallow subsurface runoff upstream of the pond (NRCS, 1997). The new bioretention basin will be at the localized low-points and collect runoff from the remaining upgradient impervious surfaces. In addition, the buffer and basin will also treat for Total Suspended Solids, Total Nitrogen, and Total Phosphorus. Removal of the pavement will reduce the amount of pollutants that enter Almy Pond.

Figure 2 (below) – Aerial of Spouting Rock Drive Area

Figure 1 (above) – Vegetated Buffers to be Located along Northwester Perimeter of Pond

Proposed Concept: Construct vegetated buffers around St. Mary's Pond. A vegetated or riparian buffer is an area of trees and shrubs adjacent to a water body that can help intercept nutrients, sediments, pesticides, and other pollutants in surface and shallow subsurface runoff (NRCS, 1997). Riparian buffers play an important role in protecting water quality and providing critical wildlife habitat along stream corridors and surrounding lakes. While there is some variability in the scientific literature regarding the width of the buffer needed to protect water quality and habitat, there is consensus that, typically, the wider the buffer the more protective of the resource the buffer becomes (Sweeney, 2014; Rhode Island Legislative Task Force, 2014).

Estimated Pollutant Removal
Total Phosphorus ≈ 40%
Total Nitrogen ≈ 50%
Total Suspended Solids ≈ 75%

Estimated Cost
$60,000

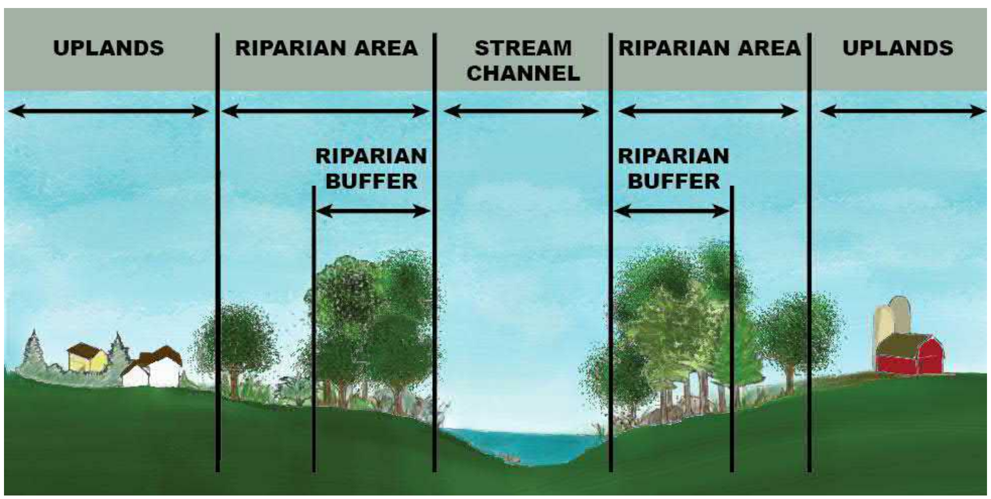


Figure 2 – Schematic of Riparian Buffer
Source: USEPA

Figure 3 – Lack of Buffer along St. Mary's Pond

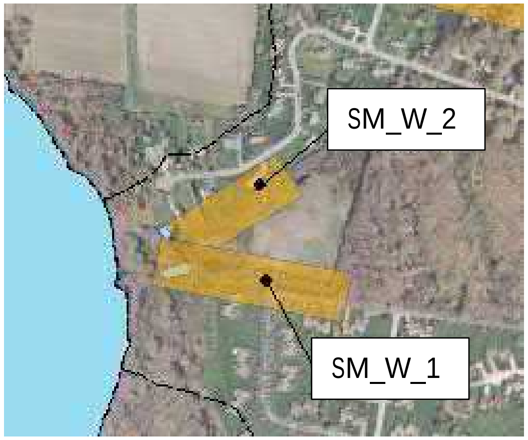


Figure 1 – WVTS Location
(Carriage Drive, Portsmouth, RI)

Proposed Concept: Retrofit the existing stormwater basin to function as a Wet Vegetated Treatment System (WVTS). WVTSs are most appropriate due to the likelihood of high groundwater in the area.

WVTSs are typically wet stormwater basins that provide water quality treatment primarily in a shallow vegetated permanent pool or wet gravel bed with emergent vegetation. Plantings that are part of the WVTS can also provide habitat benefits.

Figure 2 (above) –Typical WVTS after Planting

Figure 3 (above) – Typical WVTS after Plant Growth

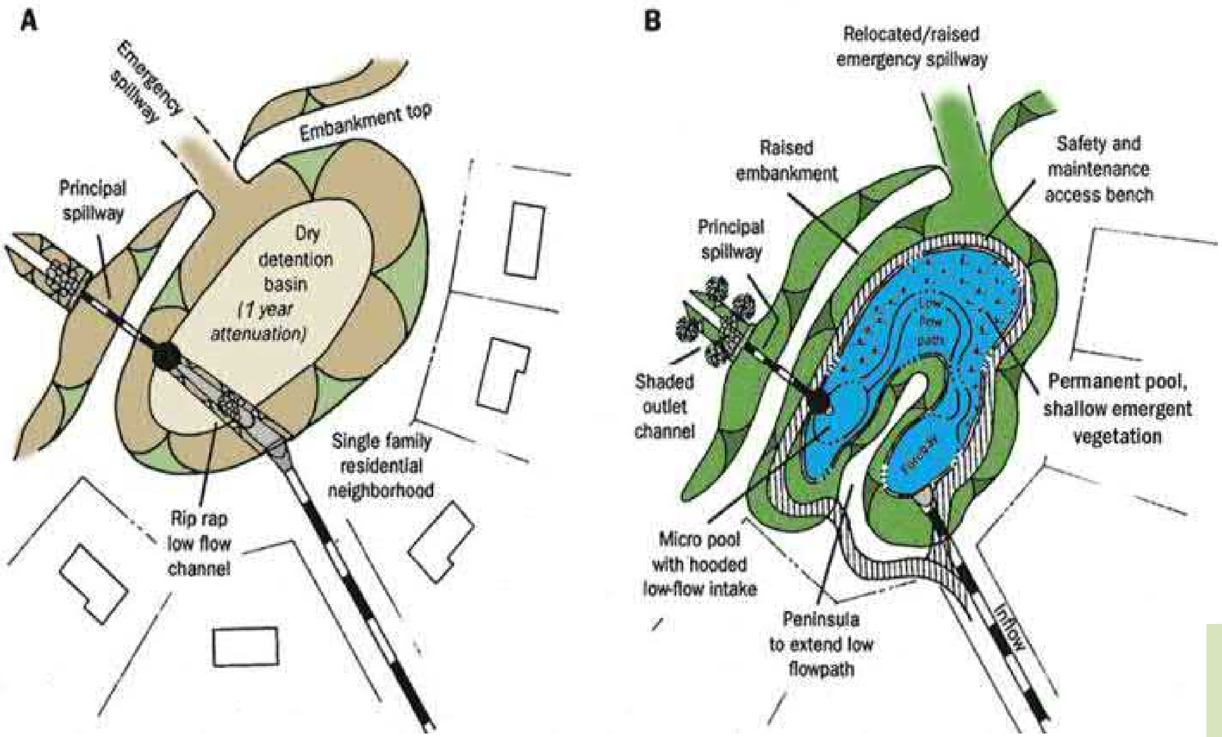


Figure 3 – Retrofit of an Existing Detention Basin (A) to a Shallow WVTS (B)
(Source: Adopted from CWP, 2007)

Estimated Pollutant Removal	Estimated Cost
Total Phosphorus ≈ 67%	$360,000
Total Nitrogen ≈ 40%	
Total Suspended Solids ≈ 56%	

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