Tighe&Bond

Manchester-by-the-Sea, Massachusetts

Opportunities for Flood Mitigation within Sawmill Brook Watershed

Prepared For:

Mary Reilly, Grants Administrator
Manchester-by-the-Sea

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Identifying Opportunities for Flood Mitigation within Sawmill Brook Watershed, Town of Manchester-by-the-Sea

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DATE: July 27, 2015

As part of the Sawmill Brook Culvert and Green Infrastructure Analysis Coastal Zone Management (CZM) Grant Project opportunities to mitigate flooding throughout the Sawmill Brook Watershed are being identified.

Opportunities to reduce runoff, both rate and volume, and to store floodwaters were identified in a two-step process consisting of a desktop evaluation and field work to verify site conditions. This memorandum summarizes the desktop evaluation, field work completed, and presents preliminary recommendations for flooding mitigation opportunities. Note that culvert sizes will be evaluated as part of the overall project Task 4 and are therefore not included in this assessment.

The approach described in this memorandum is based on the U.S. Environmental Protection Agency's (EPA's) green infrastructure guidance documents,[1] EPA Region 1's current 2003 and draft 2014 General Permits for Stormwater Discharges from Small MS4s, the Town's specific needs, and best professional judgment.

1 Overview of Flood Mitigation Practices

Green stormwater infrastructure (GSI) is a network of decentralized stormwater management practices that can capture and infiltrate rain where it falls, reducing stormwater runoff and improving the health of surrounding waterways.[2] GSI has potential to deliver multiple ecological, economic, and social benefits simultaneously, including improving air quality, reducing urban heat island effects, improving water quality and wildlife habitats, providing flood mitigation, and generally improving the community living conditions and property values. EPA emphasizes that GSI can also provide flexibility in addressing uncertainties surrounding potential droughts and increased wet weather events resulting from climate change.

Please note that there are different scales of green infrastructure, such as preservation of large areas of vegetated open space. This memorandum focuses on GSI implementation for urbanized areas.

Distributed, small scale stormwater facilities and site-design techniques mimic natural hydrologic processes by slowing down, capturing, and infiltrating rain where it falls, resulting in a reduction of stormwater volumes and peak flows and removal of pollutants. Typical GSI practices include disconnection, rain harvesting, rain gardens (bioretention), infiltration,

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[1] http://water.epa.gov/infrastructure/greeninfrastructure/

[2] Center for Neighborhood Technology (CNT) and American Rivers. *The Value of Green Infrastructure*. Available at http://www.cnt.org/repository/gi-values-guide.pdf.

street planters, underground storage, and porous/permeable pavement. Table 1, reproduced from EPA's Greening Combined Sewer Overflow Plans guidance, shows these practices and presents a brief description of each.

TABLE 1
Green stormwater infrastructure practices commonly used in urban areas (Reproduced from EPA)

Green Stormwater Infrastructure Practice	Description
 **Disconnection**	Disconnection refers to the practice of directing runoff from impervious areas such as roofs or parking lots onto pervious areas such as lawns or vegetative strips, rather than directly into storm drains
 **Rain Harvesting**	Rain harvesting systems collect runoff from rooftops and convey it to a cistern tank where the water is available for uses that do not depend on potable water, like irrigation.
 **Rain Gardens**	Rain gardens are shallow depressions filled with an engineered soil mix that supports vegetative growth. They are designed to store and infiltrate captured runoff, and retain water for plant uptake.
 **Infiltration Trench**	Infiltration trenches are gravel-filled excavations that are used to collect runoff from impervious surfaces and infiltrate the runoff into the native soil. Some systems are designed to filter runoff and reduce clogging by routing water across grassed buffer strips.
 **Street Planters**	Street planters are typically placed along sidewalks or parking areas. They consist of concrete boxes filled with an engineered soil that supports vegetative growth. Beneath the soil is a gravel bed that provides additional storage as the captured runoff infiltrates into the existing soil below. Street planters also can be designed with underdrains to avoid ponding on sites with inadequate infiltration capacity.

Porous Pavement

Permeable pavement and paver systems are excavated areas filled with gravel and paved over with a permeable concrete or asphalt mix. They may also be overset with a layer of pavers. Rainfall passes through the pavement or pavers into the gravel storage layer below where it can infiltrate at natural rates into the site's native soil.

Green Roofs

Green roofs (also known as vegetated roofs or ecoroofs) are vegetated detention systems placed on roof surfaces that capture and temporarily store rainwater in a soil medium. They typically have a waterproof membrane, a drainage layer, and a lightweight growing medium populated with plants that absorb and evaporate water.

Green infrastructure provides multiple benefits beyond flood control. GSI provides the community with many environmental and social benefits, including improving air quality, reducing urban heat island effects, improving water quality and wildlife habitats, and generally improving the community living conditions and property values. EPA emphasizes that GSI can also provide flexibility in addressing uncertainties surrounding potential droughts and increased wet weather events resulting from climate change.

Regardless of benefits, however, GSI can require a significant investment in both capital and long-term maintenance. Implementing GSI must be cost-effective in the context of flood control, the Town's municipal stormwater management program (under the NPDES "Small MS4" General Permit) for water quality improvement, and the community's greater social and environmental goals.

In additional to GSI, large areas that could be converted to flood plain or a flood storage areas (e.g. open low-lying land abutting the stream channel or wetlands) were identified. In these locations, traditional flood control structures and above-ground flood detention ponds or swales were considered to control the stream during high flow events.

2 Quantifying GSI Controls

The overall process to include GSI controls for the Sawmill Brook Watershed generally consists of the following major steps:

Step 1. A desktop (GIS-based) screening and ranking to identify and prioritize potential locations for GSI;
Step 2. Review of results of desktop screening and ranking, including site visits as needed to potential GSI locations to further evaluate feasibility, collect information, and identify other site conditions that would impact implementation;
Step 3. Conceptual sizing of GSI practices (volume treated, pollutant reduction, etc.);
Step 4. A hydrologic and hydraulic model evaluation to simulate how watershed responds to rain events with GSI included;
Step 5. Calculation of pollutant load reduction for each BMP; and
Step 6. Development of costs for implementation and evaluation of cost vs. benefit.

It is critical to understand the amount and types of green infrastructure that can be implemented, realistically and cost effectively, in a given watershed.

2.1 Desktop Screening and Ranking to Identify Initial Potential for GSI

The desktop screening was completed using Geographical Information Systems (GIS) software and numerical ranking of various criteria. Results are presented in a series of maps and tables. This effort entails a large-scale analysis, considering applicable variables that impact proper siting of each GSI practice. The goal of this process was to focus on specific locations within the Town that are most favorable and guide further assessment efforts and field work.

Overview

To analyze the suitability for implementing GSI practices at locations throughout the Sawmill Brook Watershed in Manchester-by-the-Sea, the entire Town was first divided into 10 foot by 10 foot cells using GIS software. A value (one through five, one being least favorable and five being most favorable) was assigned to each criteria to reflect compatibility of the GSI practice. Each cell was then assigned a numeric value for each of the criteria based on the tables in the next sections. For each type of GSI practice, a map was created displaying the most favored GSI sites based on the sum of all the criteria used to rank favorability. Generally, these maps show green areas for favorable areas and red areas for least favorable areas. The relative importance of each ranked criteria within the overall scoring scheme was not considered. Each criteria is considered equal.

A new map displaying all the potential highly favorable and favorable GSI locations and the municipally owned parcels was then created. Based on the primary and secondary screening the most technically viable opportunities for each GSI practice were identified. The following efforts further refine the opportunities based on potential stormwater management and water quality improvements, permitting requirements and Town preference.

Maps showing the desktop assessment steps are included in Appendix A.

2.2 Primary Desktop Screening by GSI Practice

Based on review of other communities' methodologies, Tighe & Bond evaluated feasibility by GSI practice. For example, identifying opportunities for green roofs will be fairly different than selecting potential infiltration locations. This following presents the proposed desktop screening approach using GIS.

Rain Gardens (Bioretention), Infiltration Practices, and Constructed Wetlands

Figure 1 Rain garden, Somersworth, New Hampshire *Tighe & Bond, Inc.*

Rain gardens, more formally titled bioretention systems, are small-scale landscape features designed to attenuate and treat stormwater runoff. Designs vary widely but generally consist of a soil mixture, drainage mechanism, and vegetation. As described by the Massachusetts Stormwater Handbook, rain gardens use "soils, plants, and microbes to treat stormwater before it is infiltrated and/or discharged. Rain gardens (aka bio-retention cells) are typically shallow depressions filled with a filter media consisting of sandy soil mixed with organic materials, topped with a thick layer of mulch and planted with dense native vegetation. Stormwater runoff is directed into the cell via piped or sheet flow. The runoff percolates through the soil media that acts as a filter. There are two types of bio-retention cells: those that are designed solely as an organic filter (filtering bio-retention areas) and those configured to recharge groundwater in addition to acting as a filter (exfiltrating bio-retention areas). A filtering bio-retention area includes an impermeable liner and underdrain that intercepts the runoff before it reaches the water table so that it may be conveyed to a discharge outlet, other best management practices, or the municipal storm drain system. An exfiltrating bio-retention area has an underdrain that is designed to enhance exfiltration of runoff into the groundwater. Table 2 provides a summary of raingarden performance, cost and maintenance requirements.

TABLE 2

Raingarden information

BMP Type	Target Pollutants [1]	TSS Removal Efficiency [2]	Relative Cost [3]	Maintenance Requirements [4]
Bioretention	TSS, TN, TP, Metals, Pathogens (FC)	90%[5]	$	Inspect BMP monthly, clear gross solids monthly, remove sediment as needed

1. Target pollutants are those pollutants that the BMP has been specifically designed to remove and does not include every pollutant that the BMP can remove.
   - TSS – Total Suspended Solids
   - TN – Total Nitrogen
   - TP – Total Phosphorus
   - FC – Fecal Coliform
2. Typical TSS removal efficiency per University of Massachusetts Amherst Stormwater Technologies Clearinghouse (MaSTEP).
3. For the purposes of this analysis, cost has been evaluated on a relative basis, not on project specific cost estimates.
4. Typical maintenance requirements per MassDEP Stormwater Handbook or per manufacturer's recommendations.
5. Typical TSS removal efficiency per MassDEP Stormwater Handbook.

Constructed wetlands are stormwater systems that temporarily store runoff in shallow pools that support conditions suitable for growth of wetland plants. Constructed wetlands typically consist of five basic designs: shallow marsh, basin/wetlands, extended detention wetland, pocket wetland, and gravel wetlands (or a subsurface gravel wetland).

Infiltration basins are impoundments that are constructed over permeable soils. Runoff is stored until it exfiltrates through the soil of the basin floor. Infiltration trenches are shallow excavations filled with stone, and can be designed to capture sheet flow or piped inflow. The stone provides for a somewhat underground storage area of stormwater runoff until the water infiltrates to the ground or overflows into the system. To identify potential locations for installation of bioretention and infiltration, the GIS screening process use the variables, values, and scores presented in Table 3, where a high score is desirable.

TABLE 3
Bioretention and infiltration practice favorability criteria and ranking

Favorability Ranking Score Criteria	**High** 5	**Medium** 3	**Low** 1
Depth to Bedrock	>10 feet	5 to 10 feet	0 to 5 feet
Depth to Water	>25 feet	>5 - 25 feet	0 - 5 feet
Slope of Surface	0 - 5 %	5 - 10%	>10%
Soil Permeability	Rapid (>20 in/hr)	Moderately rapid (6 to 20 in/hr)	Very slow to moderate (<6 in/hr)
Transmissivity	High (>4,000 ft^2/day)	Medium (1,400 - 4,000 ft^2/day)	Low (<1,400 ft^2/day)

Note that additional site-specific design considerations to meet the Massachusetts Stormwater Handbook Specifications for Structural Best Management Practices must be considered during a conceptual design phase.

Street Planters and Tree Box Filters

Street planters consist of concrete boxes filled with an engineering soil that support vegetative growth. Below the soil is a layer of gravel that provides additional storage as runoff captured infiltrates into the soil below the planter. Planters can also be designed with an underdrain system to avoid ponding or sites with inadequate infiltration. These are usually installed along sidewalks or parking areas.

Tree box filters are in-ground containers typically containing street trees. Runoff is directed to the tree box, where it is filtered by vegetation and soil before entering a catch basin. Tree box filters adapt bioretention principles used in rain gardens to enhance pollutant removal, improve reliability, standardize and increase ease of construction, and reduce maintenance costs.

Tree box filters typically capture and treat runoff from small, frequent storms, but they have many advantages, such as being easy to install, requiring little space, providing Town shade and habitat, and improving the aesthetic appeal of streets and neighborhoods.[3]

Three types of tree box filters are described in the next section, and Table 4 below provides a summary of performance, cost and maintenance requirements.

TABLE 4

Street planter alternatives

BMP Type	Target Pollutants [1]	TSS Removal Efficiency [2]	Relative Cost [3]	Maintenance Requirements [4]
Filterra ®	TSS, TP, TN, Copper, Zinc, Hydrocarbons	82%	$$	Inspect BMP twice/year, Clear gross solids as needed, remove sediment as needed
Modular Wetlands	TSS, TP, TN, Zinc, Copper, Hydrocarbons	74%-85%	$$$	Vacuum sediment annually, change filter as needed
Engineered Tree Box Filter	TSS, TP, TN, Copper, Zinc, Hydrocarbons	85%[5]	$	Inspect BMP twice/year, Clear gross solids as needed, remove sediment as needed

1. Target pollutants are those pollutants that the BMP has been specifically designed to remove and does not include every pollutant that the BMP can remove.
    - TSS – Total Suspended Solids
    - TP – Total Phosphorus
    - TN – Total Nitrogen
    - FC – Fecal Coliform
2. Typical TSS removal efficiency per University of Massachusetts Amherst Stormwater Technologies Clearinghouse (MaSTEP).
2. For the purposes of this analysis, cost has been evaluated on a relative basis, not on project specific cost estimates.
3. Typical maintenance requirements per MassDEP Stormwater Handbook or per manufacturer's recommendations.
4. Varies depending on design of accompanying tree trench or other stormwater BMP.
5. Typical TSS removal efficiency per New Hampshire Stormwater Manual.

3 http://www.crwa.org/hs-fs/hub/311892/file-640261436-pdf/Our_Work_/Blue_Cities_Initiative/Resources/Stormwater_BMPs/CRWA_Tree_Pit.pdf

Filterra ®

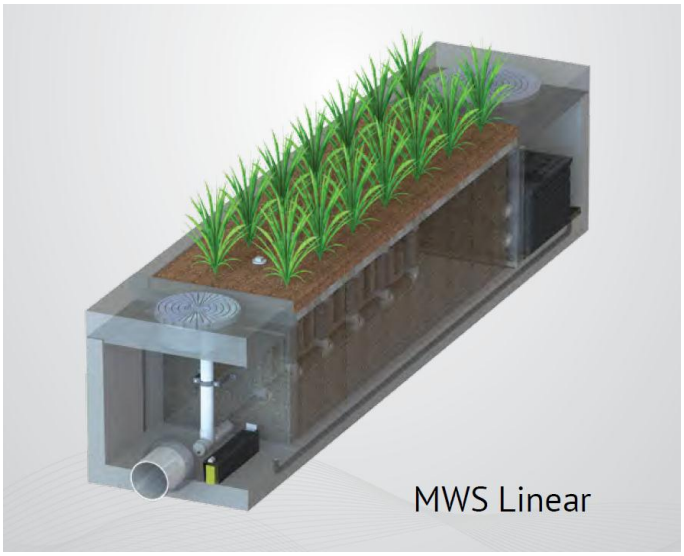
Filterra is a proprietary, all-in-one bio-retention system that is installed before discharges enter the current drainage system. It provides collection, detention, sedimentation and filtration for stormwater prior to entering the drainage system. There are several configurations to meet space restrictions and treatment level.

Figure 2 Filterra

http://www.conteches.com/products/stormwater-management/biofiltration-bioretention/filterra.aspx

Modular Wetlands

Modular Wetlands provide collection, sedimentation, filtration and detention in one system. The modules can be set in-line or off-line. These units can be easily fit into parking lot islands. The adjacent diagram shows a cross section of the system.



http://www.modularwetlands.com/

Figure 3 Modular Wetlands

Engineered Tree Box Filter

Engineered tree box filters utilize precast concrete structures to create a treatment system that provides detention, sedimentation and biofiltration.

Additional information is available in the Massachusetts Stormwater Management Handbook Volume 2 Chapter 2, available online at http://www.mass.gov/eea/docs/dep/water/laws/i-thru-z/v2c2.pdf

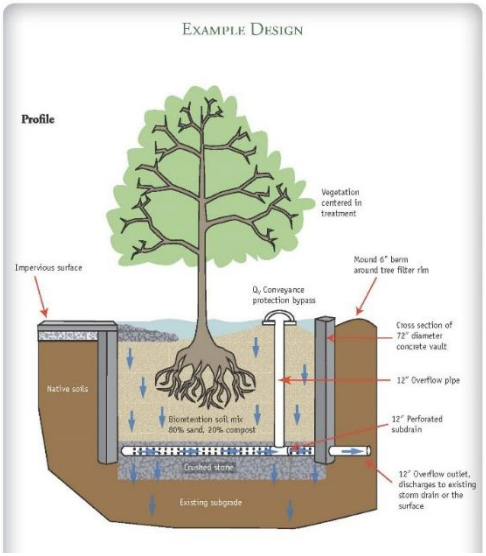


Figure 4 Engineered Tree Box Filter

Source: New Hampshire Stormwater Manual

Additional information may be found in the New Hampshire Stormwater Manual Volume 2 online at

http://des.nh.gov/organization/commissioner/pip/publications/wd/documents/wd-08-20b.pdf

Finding opportunities to install street planters can be completed using the GIS process for the bioretention and infiltration practices presented in Table 3.

Porous Pavement

Porous pavement allows rain and snowmelt to pass through it, thereby reducing the runoff from impervious area. Porous pavement can also filter some pollutants from runoff. Generally speaking, porous pavements have sufficient voids to allow rapid percolation of water through the surface. There are a number of paving surface types available to match site conditions, planned use, and aesthetic preferences:

- Permeable hot-mix asphalt (similar to hot mix asphalt but with reduced aggregate fines).
- Open-graded concrete (similar to standard pavement but with the fine aggregate and with special admixtures).
- Concrete or plastic block pavers (cast in place or precast blocks with space between each paver that can be filled with gravel, soil, or grass).
- Plastic grid systems (systems with plastic gridding that interlock and are covered with soil and grass or gravel).

Additional detail on two commonly recommended porous pavement alternatives, porous asphalt and permeable pavers, is provided below. A summary of performance, cost and maintenance requirements for porous pavement is provided in Table 5.

TABLE 5
Porous pavement alternatives

BMP Type	Target Pollutants [1]	TSS Removal Efficiency [2]	Relative Cost [3]	Maintenance Requirements [4]
Porous Asphalt	TSS	80%[5]	$	Inspect BMP annually, Vacuum sediment twice – four times a year
Permeable Pavers	TSS	76%-99%	$$	Inspect BMP annually, Vacuum sediment twice – four times a year

1. Target pollutants are those pollutants that the BMP has been specifically designed to remove and does not include every pollutant that the BMP can remove.
    - TSS – Total Suspended Solids
2. Typical TSS removal efficiency per University of Massachusetts Amherst Stormwater Technologies Clearinghouse (MaSTEP).
3. For the purposes of this analysis, cost has been evaluated on a relative basis, not on project specific cost estimates.
4. Typical maintenance requirements per MassDEP Stormwater Handbook or per manufacturer's recommendations.
5. Typical TSS removal efficiency per MassDEP Stormwater Handbook.

Porous Asphalt

According to the U.S. EPA, "porous asphalt, also known as pervious, permeable, "popcorn," or open-graded asphalt, is standard hot-mix asphalt with reduced sand or fines and allows water to drain through it. Porous asphalt over an aggregate storage bed will reduce stormwater runoff volume, rate, and pollutants. The reduced fines leave stable air pockets in the asphalt. The interconnected void space allows stormwater to flow through the asphalt, and enter a crushed stone aggregate bedding layer and base that supports the asphalt while providing storage and runoff treatment. When properly constructed, porous asphalt is a durable and cost competitive alternative to conventional asphalt."

Figure 5 Porous asphalt installation
Portsmouth, New Hampshire

The photograph to the left illustrates the dramatic difference in the stormwater absorption ability of porous asphalt (shown in the parking stall area) compared to traditional asphalt (remainder of parking lot) at Tighe & Bond's Portsmouth, New Hampshire Office.

Permeable Pavers

Figure 6 Permeable paver parking, University of New Hampshire, Durham, New Hampshire

Tighe & Bond, Inc.

Permeable pavers come in many forms, but generally are bricks that allow spacing between the joints that allows for stormwater to infiltrate below the pavers. Spacing varies depending on type of pavers.

To identify potential locations for installation of porous pavement, the same GIS screening process (criteria and ranking) to identify favorable bioretention and infiltration areas listed in Table 3 may be used.

The ideal installation for permeable paving is low-traffic streets, parking areas, driveways, sidewalks, and bike paths. It is important to consider ADA compliant access issues and potential sediment and pollutant loads when picking a site. For example, installation of a block paver walkway may not comply with ADA requirements depending on size of the spaces between the pavers. In addition, if that walkway leads to a dirt ball field, it may receive sediment loads from foot traffic, thereby reducing effectiveness and increasing maintenance requirements. It is also important to understand the level of maintenance needed for each type of permeable paving installation.

Green Roofs

Green Roofs, also known broadly as vegetated roofs, are categorized as intensive or extensive depending on the substrate depth and vegetation type, as described below.

- An intensive vegetated roof, or rooftop garden, has a deep growing medium planted with shrubs and small trees, often arranged with walking paths and seating areas.
- An extensive vegetation roof covers a rooftop with shallow layers (<6 inches) of lightweight growing medium, low-growing vegetation, subsurface drainage, and a waterproof membrane.

For this analysis, ideal sites would accommodate extensive vegetative roofs to provide greater stormwater management benefit that are less challenging to install.

To identify potential locations for installation of vegetated roofs, the Town should consider if any municipal or commercial parcels are undergoing construction and evaluate if there is a potential opportunity to install green roofs. Generally speaking, roof slope between 5 and 30 degrees is most favorable and greater than 40 degrees is considered not feasible. Understanding the feasibility of a public/private partnership (applicable to non-municipal installations) and whether or not the candidate area has adequate structural support to hold the additional weight of an extensive green roof, which is generally 10 to 30 pounds per square foot[4] when it is fully saturated, will also be required. Regardless of installation, consideration must be given to providing irrigation to saturate plants during dry periods and proper drainage to avoid mosquito breeding.

[4] http://www.mass.gov/eea/docs/doer/green-communities/library/green-roof-boston-st2009.pdf

For example, a municipal parcel with planned new construction would be a great candidate, as the roof could be designed to accommodate a GI practice. On the other end of the spectrum, a commercial or residential parcel with no planned development or redevelopment that has a reasonably flat roof, and is a promising public/private partnership opportunity, may be a candidate if the structure is able to support the weight of the green roof.

Disconnection and Rain Harvesting

Downspout disconnection, or redirecting roof drains, involves diverting rooftop drainage away from the combined sewer and into infiltration, detention, or storage facilities. In areas that allow infiltration, roof drainage can be conveyed to bioretention cells, dry wells, or simply dispersed onto a lawn or landscaped area. On sites that do not have good potential for infiltration, roof drains can instead be routed into storage tanks or lined bioretention facilities that discharge to the combined system, allowing peak flows to be reduced during extreme weather events. Rainwater harvesting refers to the practice of collecting rainwater from rooftops or other surfaces and storing it for water use. After pretreatment by screens and/or first flush diverters, collected rainwater is stored in barrels or cisterns. This captured rainwater can be used on site for landscape irrigation, non-potable household uses, and industrial or commercial uses. Depending on the use, a treatment system may be needed. The key siting constraints are related to roof drainage configuration, site conditions for infiltration or storage, and re-use potential.

Due to the nuances and details associated with identifying sites for disconnection of downspouts in GIS process, we have not included this analysis as part of the Desktop Assessment and instead recommend the Town assess the practice as project and budget allows.

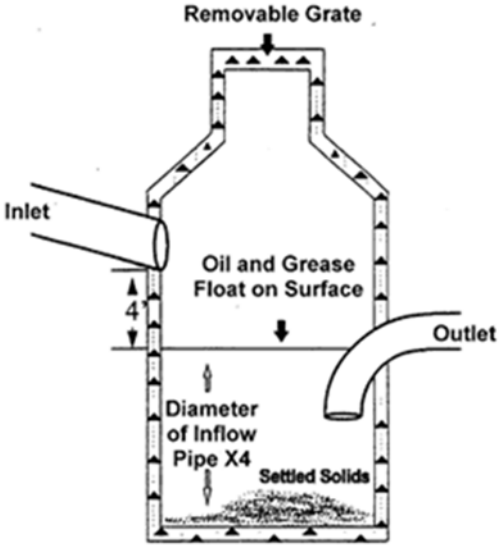
In addition, due to the challenges of implementing rainwater harvesting, including conflicts with plumbing code and challenges addressing other local and state requirements, we have not included this GSI practice in the Desktop Assessment. Rainwater harvesting can be considered on a case-by-case basis as site conditions and local/state code allows.

Other Roadway Practices to Reduce Pollutants

Other types of roadway treatment includes conventional deep sump catch basins and structural filters that can be added in combination with traditional pretreatment BMPs to provided additional pollutant removal. Table 6 below provides a summary of performance, cost and maintenance requirements.

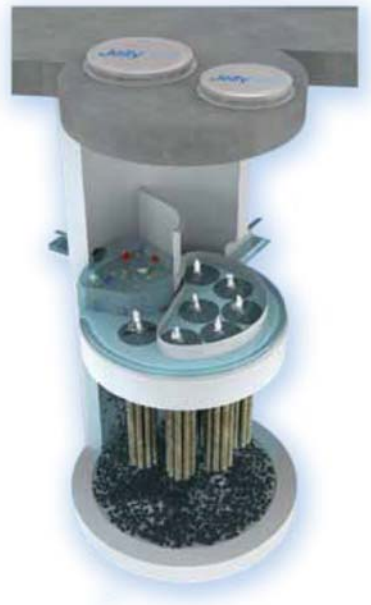
Pretreatment BMPs

Deep sump catch basins with hoods are underground structures designed to remove trash, debris, and coarse sediment from stormwater runoff. These structures also serve as oils water separators and can function as temporary emergency spill containment.



Deep Sump Catch Basin

Structural Filters



According to the manufacturer's website, "the **Jellyfish Filter** is a stormwater quality treatment technology featuring high surface area, high flow rate membrane filtration, at low driving head. By incorporating pretreatment with light-weight membrane filtration, the Jellyfish Filter removes a high level and a wide variety of stormwater pollutants. The high surface area membrane cartridges, combined with up flow hydraulics, frequent backwashing, and rinse able/reusable cartridges ensures long-lasting performance."

More information is available online at:
http://www.conteches.com/jellyfish

TABLE 6
Roadway BMP alternatives

BMP Type	Target Pollutants [1]	TSS Removal Efficiency [2]	Relative Cost [3]	Maintenance Requirements [4]
		Pretreatment		
Deep Sump Catch basin with Hood	TSS, Hydrocarbons	39% (pretreatment only)	$	Inspect BMP annually, clear gross solids quarterly, vacuum sediment quarterly
		Filters		
Jellyfish Filter ®	TSS, TP, Metals	87%-89%	$$$	Inspect BMP annually, vacuum sediment twice/year

1. Target pollutants are those pollutants that the BMP has been specifically designed to remove and does not include every pollutant that the BMP can remove.
   - o TSS – Total Suspended Solids
   - o TN – Total Nitrogen
   - o TP – Total Phosphorus
   - o FC – Fecal Coliform
2. Typical TSS removal efficiency per University of Massachusetts Amherst Stormwater Technologies Clearinghouse (MaSTEP).
3. For the purposes of this analysis, cost has been evaluated on a relative basis, not on project specific cost estimates.
4. Typical maintenance requirements per MassDEP Stormwater Handbook or per manufacturer's recommendations.
5. Typical TSS removal efficiency per MassDEP Stormwater Handbook.

2.3 Secondary Screening by Parcel Ownership

Following the initial feasibility screening for each type of GSI practice, a second GIS-based desktop evaluation was completed to identify municipally owned property properties. The parcels are highlighted on Figure A6 in Appendix A.

2.4 Permitting and Environmental Considerations

Following the primary and secondary screening for each type of GSI, a Town-wide GIS-based evaluation was completed to understand additional criteria that affect permitting requirements and other environmental issues that may impact the desirability of implementing each GSI practice. This evaluation will also inform costs developed later in the project. The criteria listed in Table 7 were evaluated. The output of this exercise is a map showing the extent of the criteria. Please note that there are no surface water protection areas in Manchester by the Sea.

TABLE 7
Permitting and environmental considerations criteria and ranking

Criteria	Favorable	Least Favorable
Is the site within a FEMA flood zone?	No	Yes
Is the site within a wellhead protection area?	No	Yes
Is the site with NHESP Priority or Estimated Habitat?	No	Yes
Is the site within close proximity to a certified or potential vernal pool (100 feet)?	No	Yes
Is the site within close proximity to a parcel with a septic system (100 feet)?	No	Yes
Is the site in protected open space?	No	Yes
Is the site in a Massachusetts Historical Commission inventoried area or site?	No	Yes
Is the site within Wetlands jurisdiction?	No	Yes
Is the site within close proximity to a parcel with contamination (100 feet)?	No	Yes
Is the site within an area that may be impacted by sea level rise?	No	Yes

2.5 Qualitative Considerations

The final step of the process includes consideration for other components that make the project more desirable or feasible, but cannot easily be considered using GIS. Overall understanding of the level of community support for the different types and locations of GSI, and the Town's ability to construct, access, and maintain the GSI controls, particularly when GSI is installed on private property, is important to identified as part of this process.

In addition, benefits to water quality should be considered. Drivers for water quality stormwater retrofits include likely future "Small MS4" General Permit requirements to evaluate and install stormwater treatment retrofits in impaired watersheds with or without a complete Total Maximum Daily Load (TMDL) study. The Town's MS4 discharges to other impaired waterbodies without final TMDLs. According to the Proposed Massachusetts 2014 List of Waterbodies, a number of waterbodies within the Town are impaired by solids and bacteria (both E. coli and fecal coliform).

Prior to constructing any flood mitigation projects or BMPs, the Town will evaluate the following questions to consider other factors influencing implementation:

- How extensive is the level of coordination needed to implement the GSI practice?
- What is the level of community support for the GSI practice, both community-wide and in the neighborhood?
- Is the proposed location of the GSI practice within a known flood-prone area? Does this area contribute to flooding problems downstream in the watershed?
- Will this installation of the GSI practice enhance or preserve existing natural vegetation?
- Will the project cultivate educational opportunities?
- Will overhead or underground utilities need to be relocated for installation?
- How extensive are maintenance requirements and does the Town have the ability to complete maintenance?
- Will the project improve aesthetics for the area?
- Will the project improve wildlife habitat?
- Does this project overlap with another planned improvement to a building, parking area, or infrastructure on the site?

3 Field Work

Tighe & Bond staff meet with the Town on May 18, 2015, to review the findings of the desktop assessment and understand any preferred site to visit for field work to assess favorable locations for installation of a management practice. At this meeting, input on constraints, known concerns, and access issues were discussed. The handout from the May 18th meeting is included in Appendix B. The Town suggested field assessments at the following locations:

- Parking lot behind Manchester-by-the-Sea Fire Station on School Street
- Knight Circle
- Protected open space with access on Friend Street
- Downtown School Street culvert (23)
- Blue Heron Lane area (three streets)
- Essex Country Club (golf course)
- Schools
- Artificial turf field; and
- Conservation Parcel located between Ancient Country Way and Summer Street.

The only access issues cited were related to the privately owned properties including the Essex Country Club.

Based on the desktop screening and the Town's input, Tighe & Bond staff completed two days of field work to evaluate 17 sites throughout the watershed. Tighe & Bond staff looked for opportunities to reduce runoff volumes and flows and store floodwaters, through construction of green infrastructure or through more traditional flood management alternatives (creation of floodplain). Parcel maps and photographs were used to document the sites including existing drainage, extent of impervious area, and obstacles to construction or access. The map included in Appendix C shows the locations of sites assessed.

Culvert sizing will be evaluated as part of the modeling completed under Task 4 of the project and therefore was not considered under this Task.

3.1 Sites Assessed

Table 8 shows a list of the sites assessed and a summary of observations. The figure in Appendix C shows the locations of these sites. Note that permitting needs are further discussed in Section 4.

TABLE 8
Summary of sites assessed

Site Name	Site Description	Summary of Observations
Site 1: Parking lot abutting Town Fire Station at 12 School Street	Parking lot is heavily used by fitness club located at 6 School Street. Parking lot abuts stream channel and Central Pond.	There may be opportunities to install a LID BMP. Flood mitigation (such as subsurface storage) would be cost prohibitive given subsurface conditions related to bedrock and groundwater.
Site 2: Knight Circle	Narrow residential roadway with private property conflicts within the right of way and no municipally owned land abutting street.	Installation of a LID BMP or flood control on municipally owned property or right of would be challenging given the narrow roadway and extensive private property. It would be feasible to install rain gardens on private property, however, maintenance agreements, deed restrictions, and potentially easements would be needed.
Site 3: Access to Open Space off Friend Street	The access path to the open space/hiking area off Friend Street experiences heavy erosion and causes extensive runoff to be discharged to Friend Street during precipitation events, due to the steep slope that is mostly bedrock.	Given the slope and subsurface conditions, there is limited opportunity to install a LID BMP or flood control device.
Site 4: Municipal Land upstream of School Street Culvert 23	The small parcel upstream of the School Street culvert (23), just to the east of School Street and north of Brook Street, is vegetated but otherwise largely open.	Given the vegetation and elevation of the parcel in relation to the stream there may be an opportunity to create a small flood storage area abutting the Sawmill Brook stream channel. Further information about historic

Site Name	Site Description	Summary of Observations
		stone wall construction restrictions is needed.
Site 5: Gravel Parking Lot for Turf Field at intersection of Norwood Avenue and Brook Street	Parking lot for turf field is gravel. Sediment migrates off site to Norwood Avenue during precipitation events.	May be an opportunity to replace gravel with porous asphalt, or repave parking lot and install other LID BMPs.
Site 6: Municipal Land Abutting Stream	Sawmill Brook flows through lightly vegetated (with some large diameter trees) municipal land in the area just upstream of Culvert 22 and downstream of the Elementary and High Schools.	May be an opportunity to create flood storage areas on either side of stream channel based on slope and vegetation.
Site 7: Manchester-Essex Regional High School	Extensive parking and driveway areas on school property.	Although site was recently redeveloped, may be an opportunity to install surface LID BMPs such as bioretention or tree box filters. Need to obtain existing drainage design to confirm presence of existing stormwater BMPs.
Site 8: Manchester-by-the-Sea Elementary School	Extensive parking and driveway areas on school property. Site also appears to have a rain garden next to tennis courts.	May be opportunity to re-pave parking lot and install porous asphalt for parking stalls, tree box filters, and other bioretention cells in parking lot. A survey crew was on-site during site visit. Need to obtain paving schedule for parking area.
Site 9: Golf Course	Sawmill Brook flows through municipally owned land on golf course that is open with limited vegetation.	May be opportunities to create flood storage given extensive open space bordering stream channel.
Site 10: Town Conservation land at the intersection of Forest Street and Summer Street	Site is heavily vegetated with no impervious cover. Unknown where existing drainage system discharges.	Based on lack of impervious cover abutting parcel, slope of roadways, and existing drainage system, limited opportunity to install LID BMPs or flood control devices was observed.
Site 11: Town Land off Forest Street north of Culvert 8	Side is naturally vegetated area north of Forest Street.	Site is north of Forest street and is naturally vegetated with no impervious cover, limited opportunity to install LID BMPs or flood control devices was observed.
Site 12: Town Land off Forest Street downstream of Culvert 11	Land owned by Town downstream of Culvert 11 has natural channel that provides flood storage on banks.	Site is downstream of culvert 11 and already provides natural flood attenuation, limited opportunity for LID BMPs or flood control was observed.

Site Name	Site Description	Summary of Observations
Site 13: Culvert 4 at the end of Atwater Avenue	This culvert was rebuilt recently and appears to be sized appropriately to allow stream passage.	Would be cost-prohibitive to install flood management structure on upstream side.
Site 14: Town Land north of Culvert 6 (to the east of School Street)	Land owned by Town upstream of Culvert 6 is natural channel that provides flood storage on bands.	Limited opportunity for LID BMP or flood mitigation was observed.
Site 15: Culvert 2 on Old School Street	Roadway is old and has surrounding wetland area has potential to provide flood storage.	May be opportunity to raise elevation of abandoned road and resize culvert including installation of flood control device (e.g. weir) to detain upstream water for flood reduction.
Site 16: Culverts 12,13,15 on The Plains, Millets Lane, and Blue Heron Lane	Three residential areas with two-lane roads and a small municipally-owned parcel located between.	Area is too low gradient and Town land too small for LID BMP or flood control structure to be cost effective. Culvert sizes can be further evaluated during modeling phase.
Site 17: Land Upstream from Culvert 9 off Pine Street	Land is naturally good wetlands areas with recent stream restoration completed.	Limited opportunity to install LID BMPs or flood control devices observed due to recently completed stream restoration.

4 Probable Permitting Requirements

Tighe & Bond compiled a list of local, state, and federal permits that may be required to implement any of the GSI or flood mitigation practices identified. The Table 9 presents a list of all permits reviewed, including potential permit triggers, applicability to the projects, preparation time and permit timelines, fees, and relevant links and assumptions. Based on our evaluation in Section 3, a number of permits will be potentially needed for construction of flood control or GSI projects. In some cases, projects may have more significant hurdles to permitting than others.

Based on our preliminary evaluation, the following permits likely apply to all of the proposed projects:

- Order of Conditions from the Manchester-by-the-Sea Conservation Commission (prepare and submit at least three - six months in advance of releasing bid documents)
- Local permits (Street Opening, Trench Permit, potentially Tree Removal Permit)

The following permits may apply to selected projects depending on final design and whether or not projects are "grouped" for construction:

- Environmental Notification Form under the Massachusetts Environmental Policy Act (MEPA) to obtain a Certificate from the Secretary
- EPA Construction General Permit
- MassDOT Highway Access Permit
- Chapter 91 Waterways License
- Project Notification Form to the Massachusetts Historical Commission (file as soon as final layout is determined)

Table 9: Overall Permitting Review
Sawmill Brook Flood Storage and GSI Projects

Permit Name	Permit Form	Permitting Agency	Potential Permit Triggers [2]	Potential for Project to Require Permit and Reason	Preparation Time & Permit Timeline	Application Fee	Permit Reference	Assumptions/Notes
Order of Conditions	BRP WPA Form 3 - Notice of Intent (NOI) & Documents per Local Bylaw and Regulations	Manchester-by-the Sea Conservation Commission	work in resource area including Riverfront, BVW, Bank, and/or Buffer	Yes, project is within Riverfront and Buffer and potentially within Bank	**30 Days Preparation Time**: Prepare NOI plans, forms, and narrative; calculate resource area disturbance; potential wetland replication; stream crossing methodology; No stormwater design. **90 days Permit Timeline:** submit 20 days prior to scheduled conservation hearing; Commission meetings are typically held every other Tuesday; anticipate 2 or 3 hearings and peer review back & forth = approx. 1.5 months ; 2 weeks for agent to write order; 2 weeks for appeal.	Waived	http://www.manchester.ma.us/pages/manchesterma_conservation/index http://www.mass.gov/eea/agencies/massdep/water/approvals/wetlands-and-waterways-forms.html#4	NOI includes wetland delineation approval. Order of Conditions is for 3 years, but may be extended for an additional 3 year period.
Certificate of the Secretary of Energy and Environmental Affairs on the Environmental Notification Form [1]	Environmental Notification Form (ENF)	Massachusetts Environmental Policy Act (MEPA) Executive Office of Energy and Environmental Affairs (EEA)	(1) alteration of 500 or more linear feet of bank along a fish run or inland bank; (2) alteration of 5,000 or more sf of bordering or isolated vegetated wetlands; (3) alteration of one half or more acres of any other wetlands; (4) Dredging of 10,000 or more cy of material; (5) Disposal of 10,000 or more cy of dredged material, unless at a designated in-water disposal site.	Project triggers thresholds related to alteration of inland bank, bordering or isolcated vegetated wetland, and may trigger historical or archeaological thresholds.	**30 days Preparation Time**: includes preliminary resource area disturbance calculation **45 days Permit Timeline**: submit 1st or 15 of month; comments from agencies due 30 days; MEPA agent decision 15 days later.	None	http://www.mass.gov/eea/agencies/mepa/	An Environmental Impact Report will not be required.
Construction General Permit	NPDES Notice of Intent (NOI)	United States Environmental Protection Agency (US EPA)	construction activities (which include soil disturbing activities such as clearing, grading, excavating, stockpiling, etc.) that disturb one or more acres.	Yes, project may disturbs one or more acres	**14 Days prior to Land Disturbing Activities**: Notice of Intent submitted to EPA online using CDX system. SWPPP must be prepared and signed in advance (typically takes 1 week)	None	http://cfpub.epa.gov/npdes/stormwater/cgp.cfm	Site specific Stormwater Pollution Prevention Plan (SWPPP) shall be prepared
Dewatering General Permit	NOI	US EPA	construction dewatering of groundwater intrusion and/or storm water accumulation from sites less than one acre, and short-term and long-term dewatering of foundation sumps into waters of the Commonwealth of Massachusetts (including both Commonwealth and Indian country lands) and the State of New Hampshire.	No, CGP covers the work	Submit an NOI to EPA and MassDEP, post-marked at least **21 days** prior to the commencement of discharge.	None	http://www.epa.gov/region1/npdes/dewatering.html	
Highway Access Permit	Application for Permit to Access State Highway	Massachusetts Department of Transportation (MassDOT)	physical work performed within the State Highway Layout	Yes	**10 days:** fill out form and submit design drawings depicting work in right of way.	Waived	http://www.massdot.state.ma.us/highway/DoingBusinessWithUs/PermitsRoadAccessPrograms/ApplicationsforPermitstoAccessStateHighway.aspx	
401 Water Quality Certificate (WQC)	BRP WW 07 (minor), BRP WW 08 (major), BRP WW 09 (project that previously received WQC) Dredging	Massachusetts Department of Environmental Protection (MassDEP)	dredging of 100 cubic yards or greater in areas subject to federal permitting under the Army Corps of Engineers. Two categories for WQC: 100 cubic yards to less than 5,000 cubic yards is classified as a "minor" WQC project while dredging 5,000 cubic yards or greater is classified as "major" WQC project	No	**348 days** for approval from DEP including a 180 day "response to deficiency" period	Waived	http://www.mass.gov/eea/agencies/massdep/water/approvals/wetlands-and-waterways-forms.html	The WQC review is to ensure that activities to be undertaken under a federal ACOE permit (or other federal permit authority) will also result in being in conformance with Massachusetts laws and regulations. Regulatory authority for this 401 WQC is found at 314 CMR 9.00. If any dredging is to occur in an "Outstanding resource Water" (ORW) as classified in the Massachusetts Surface Water Quality Standards (314 CMR 4.00), the proponent must file notice with the Executive Office of Energy and Environmental Affairs- MEPA Office. The MEPA process must be completed (with a Secretary's certification) before any MassDEP 401 WQC issuance can occur. The 401 WQC process requires sampling and analysis of the areas proposed
Chapter 91 Waterways License	BRP WW 04 (Req for Applicability, BRP WW 01,03,14,15,16,17 (License), BRP WW 06,12 (Simplified License)	MassDEP	Placement or construction of any structure, regardless of size, whether permanent or seasonal. Examples of typical structures include, but are not limited to: piers, wharves, dams, seawalls, weirs, booms, breakwaters, bulkheads, ripraps, revetments, jetties, piles, lines, groins, roads, culverts, bridges, buildings, parking lots, cables, **pipes**, conduits, tunnels, wires, floats, etc., within jurisdictional areas (flowed tidelands and filled tidelands).	No	Pre-application Meeting can be requested. ENF Filing must occur before filing application for a Chapter 91 License. Following application, process includes determining water dependency, public notice period (15 to 30 days), public hearing, written determination, appeal period, file completion, and finally recording license and paying fee, and certificate of compliance (within 60 days of recording)	TBD	http://www.mass.gov/eea/agencies/massdep/water/approvals/wetlands-and-waterways-forms.html	
Department of the Army General Permit Commonwealth of Massachusetts	GP 9. Utility Line Activities (Sections 10 & 404; tidal and non-tidal waters of the U.S.	United States of America Army Corps of Engineers (ACOE)	Work and structures that are located in, over or under any navigable waters of the U.S. The construction, maintenance, or repair of utility lines, including outfall and intake structures, and the associated excavation, backfill, or bedding for the utility lines in tidal and non-tidal waters of the U.S.(Refer to Permit for definition of permit categories and more detail on permit triggers.)	No	**30 days:** Provided NOI submitted and disturbance calculated and methodology for stream crossing determined. US Army Corps goals for review - 60 days Pre-Construction Notification filing, 120 days including 30 day public notice	None	http://www.nae.usace.army.mil/Missions/Regulatory/StateGeneralPermits/MassachusettsGeneralPermit.aspx	Category 1 permit is not subject to review; Category 2 permit requires application submittal and review by US Army Corps; Category 3 is an individual permit required for complicated projects not eligible under the General Permit.

Table 9: Overall Permitting Review
Sawmill Brook Flood Storage and GSI Projects

Permit Name	Permit Form	Permitting Agency	Potential Permit Triggers [2]	Potential for Project to Require Permit and Reason	Preparation Time & Permit Timeline	Application Fee	Permit Reference	Assumptions/Notes
MHC Determination [3]	Project Notification Form	Massachusetts Historical Commission (MHC)	Any new construction projects or renovations to existing buildings that require funding, licenses, or permits from any state or federal governmental agencies must be reviewed by the Massachusetts Historical Commission (MHC) for impacts to historic and archaeological properties. It is the nature of the federal or state agency involvement that triggers MHC review, not listing in the National or State Registers of Historic Places. A listing in either register does not necessarily require review and likewise, lack of listing does not eliminate the need for review.	Project is within historic districts and there are numerous historic properties listed abutting the proposed sewer route. Submit a Project Notification Form to MHC once the final layout is determined.	**30 days** for initial response. If further evaluation is needed, the review time varies dependent on project and site complexity.	None	http://www.sec.state.ma.us/mhc/mhcrevcom/revcomidx.htm	If the project site is determined to have Historical or Archaeological significance, a MEPA filing may be triggered.
Massachusetts Endangered Species Act (MESA) Project Review Decision [5]	MESA Information Request Form	Natural Heritage & Endangered Species Program (NHESP) of the Massachusetts Division of Fisheries and Wildlife	Site specific rare species information for regulatory review can be requested from the NHESP through the MESA Information Request Form. It is highly recommended that project proponents request this information prior to development of site plans, especially if the project falls within Priority Habitat or Estimated Habitat for rare species.	No, project is not within Priority Habitat or within Estimated Habitat, nor are any Certified Vernal Pools located near the project.	**30 day** response time	$50.00	http://www.mass.gov/eea/agencies/dfg/dfw/natural-heritage/regulatory-review/mass-endangered-species-act-mesa/	(1) If a project falls within Priority Habitat of Rare Species and does not qualify for a MESA filing exemption, proponents must file with the NHESP. Priority Habitat is defined as "the geographic extent of Habitat for state-listed species" as delineated by the Division pursuant to 321 CMR 10.12. (2) Proponents should note that if they are required to file with the local Conservation Commission pursuant to the Wetlands Protection Act and the proposed project is within Estimated Habitat for state-listed wildlife, a copy of the filing must be submitted to the NHESP, even if the project qualifies for a MESA filing exemption
Street Opening / Excavation Permit	Street Opening Permit	Manchester by the Sea Department of Public Works	required for all paving, excavating, curb cuts, landscaping, retaining wall construction, conduit installation, etc., on street layout, including driveways	Yes	Variable	Waived		
Trench Permit	Trench Permit	Manchester by the Sea Department of Public Works	trenching greater than 2' deep on public property	Yes	Variable	Waived		
Tree Removal	None	Manchester by the Sea Department of Public Works	pruning or removal of a tree in the public road layout. For trees along scenic roads, also requires planning board approval	Maybe, depends on final location of GI BMPs.	Variable	Waived	http://www.manchester.ma.us/pages/manchesterma_dpw/Trees	
Local Permits	TBD	Planning Board, Zoning Board of Appeals	Construction of pump stations	No	TBD	TBD	TBD	

Footnotes

(1) The Certificate of the Secretary of Energy and Environmental Affairs on the Environmental Notification Form is not a permit. It is a finding pursuant to the Massachusetts Environmental Policy Act (MEPA).
(2) List of Potential Permit Triggers is not an all inclusive list, but rather a potential list for the specific recommended project as currently scoped.
(3) MHC does not issue a permit. MHC issues a determination on whether there are known or anticipated historic or archaeological properties within the project area, whether the project is likely to affect historic or archaeological properties, whether further MHC review is warranted, whether additional information is needed to assess the likelihood that historic or archaeological properties will be affected by the proposed project, whether an archaeological survey or historic study of the property is warranted, and what, if any, avoidance or mitigation measures may be appropriate.
(4) The US Army Corps will alternately accept MassDEP's WQC or Chapter 91 application forms for its review provided the forms were already sent to MassDEP.
(5) MESA Project Review Decision is not a permit.

5 Potential Opportunities for Green Infrastructure and/or Flood Control

Based on results of the desk-top screening and field observations, sites 1, 4, 5, 6, 7, 8, 9 and 15 have the most opportunity for management of stormwater runoff or flooding within the Sawmill Brook Watershed. The sites are discussed in more detail below.

Site 1: Parking lot abutting Town Fire Station at 12 School Street

Summary

Site 1 includes approximately 11,300 square foot parking area between 6 School Street and 10 School Street (Fire Station) shown in Figure 7. This lot slopes down towards Central Pond from School Street. Figure 8 shows the site and local conditions. There may be an opportunity to install a LID BMP (such as a rain garden or tree box) or permeable asphalt in the area abutting the Pond. Given the site constraints, flood mitigation options will likely not be cost effective and therefore are not recommended.

Figure 7 View of Fire Station with parking lot on the left

Additional Assessment Recommendations

- Site-specific subsurface investigation including geotechnical evaluation and depth to groundwater
- Identification of utilities
- Hydraulic model to install a LID BMP
- Coordination between fire department and private business to verify access needs for public safety and parking needs

Probable Permits

- Order of Conditions from Manchester Conservation Commission
- Project Notification Form to Massachusetts Historical Commission
- Local permits as needed

LEGEND

Municipal Parcel

Potential Work Area

SITE 1
PARKING LOT NEXT TO FIRE STATION

Manchester-by-the-Sea, MA

Figure 8

Tighe&Bond
Consulting Engineers
Environmental Specialists

0 50
Feet
1 " = 50 '

NOTES

Data sources: Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

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Site 4: Municipal land adjacent to Sawmill Brook, near culvert 23

Summary

Site 4 includes a potential opportunity to create a flood storage area to the left side of the Sawmill Brook looking upstream from Culvert 23 on School Street (Figure 9). Figure 10 shows the site and local conditions. The project would include re-grading the bank area to allow for storage of flood waters by increasing the floodplain. The area potentially disturbed totals up to 0.1 acres, and additional disturbance may be caused by culvert work.

Figure 9 Potential flood storage on northern bank

Additional Assessment Recommendations

- Confirm jurisdiction of Historic Commission over stream channel and culvert
- Survey of site including identification of trees
- Identification of utilities

Probable Permits

- Order of Conditions from Manchester-by-the-Sea Conservation Commission
- Project Notification Form to Massachusetts Historical Commission
- 401 Water Quality Certificate (depending on amount of material in stream channel removed)
- MEPA Environmental Notification Form (depending on need for 401 Water Quality Certificate)
- Local permits as needed, including tree removal

LEGEND

Culvert

Municipal Parcel

Potential Work Area

SITE 4
UPSTREAM OF
CULVERT 23

Manchester-by-the-Sea, MA

Figure 10

Tighe&Bond
Consulting Engineers
Environmental Specialists

0 50
Feet
1 " = 50 '

NOTES

Data sources: Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

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Site 5: Parking lot for Turf Field

Summary

Site 5 includes the existing gravel parking lot for the Town's artificial turf recreational fields off of Norwood Avenue and Brook Street (Figure 11). Figure 12 shows the site and local conditions. This parking lot could be resurfaced with porous asphalt, or, could have other LID BMPs installed (e.g. tree box filters, in conjunction with paving the area).

Figure 11 Existing parking conditions at recreation area

Additional Assessment Recommendations

- Site-specific subsurface investigation including geotechnical evaluation and depth to groundwater
- Identification of utilities
- Survey of site

Probable Permits

- Order of Conditions from Manchester-by-the-Sea Conservation Commission
- Local permits as needed

LEGEND

Culvert

Municipal Parcel

Potential Work Area

SITE 5
PARKING LOT FOR
TURF FIELD

Manchester-by-the-Sea, MA

Figure 12

Tighe&Bond
Consulting Engineers
Environmental Specialists

0 50
Feet
1 " = 50 '

NOTES

Data sources: Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

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Site 6: Land abutting Stream Channel on Turf Field

Summary

Site 6 consists of municipal land abutting Sawmill Brook upstream of Culvert 22 shown in Figure 13. Figure 14 shows the site and local conditions. This area is lightly vegetated (with some large diameter trees) with opportunity to create flood storage on the bank of the stream. A project would include re-grading the area and installing natural plantings while leaving the large diameter trees. Approximately 13,000 square feet of area could potentially be utilized.

Figure 13 View of Sawmill Brook channel

Additional Assessment Recommendations

- Site-specific subsurface investigation including geotechnical evaluation and depth to groundwater
- Identification of utilities
- Survey of site including identification of trees

Probable Permits

- Order of Conditions from Manchester-by-the-Sea Conservation Commission
- 401 Water Quality Certificate (depending on amount of material in stream channel removed)
- MEPA Environmental Notification Form (depending on need for 401 Water Quality Certificate)
- Local permits as needed, including tree removal

LEGEND

Culvert

Municipal Parcel

Potential Work Area

SITE 6
AREA UPSTREAM OF CULVERT 22

Manchester-by-the-Sea, MA

Figure 14

Tighe&Bond
Consulting Engineers
Environmental Specialists

0 10
Feet
1 " = 100 '

NOTES

Data sources: Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

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Site 7: High School

Summary

Site 7 includes several areas on the Manchester Essex Regional Middle High School grounds. Figure 15 shows the main parking lot and Figure 16 includes an overview map showing the lot and local conditions. Although the High School was recently reconstructed, there may be opportunities to manage additional runoff through installation of LID BMPs such as rain gardens or installation of porous pavement.

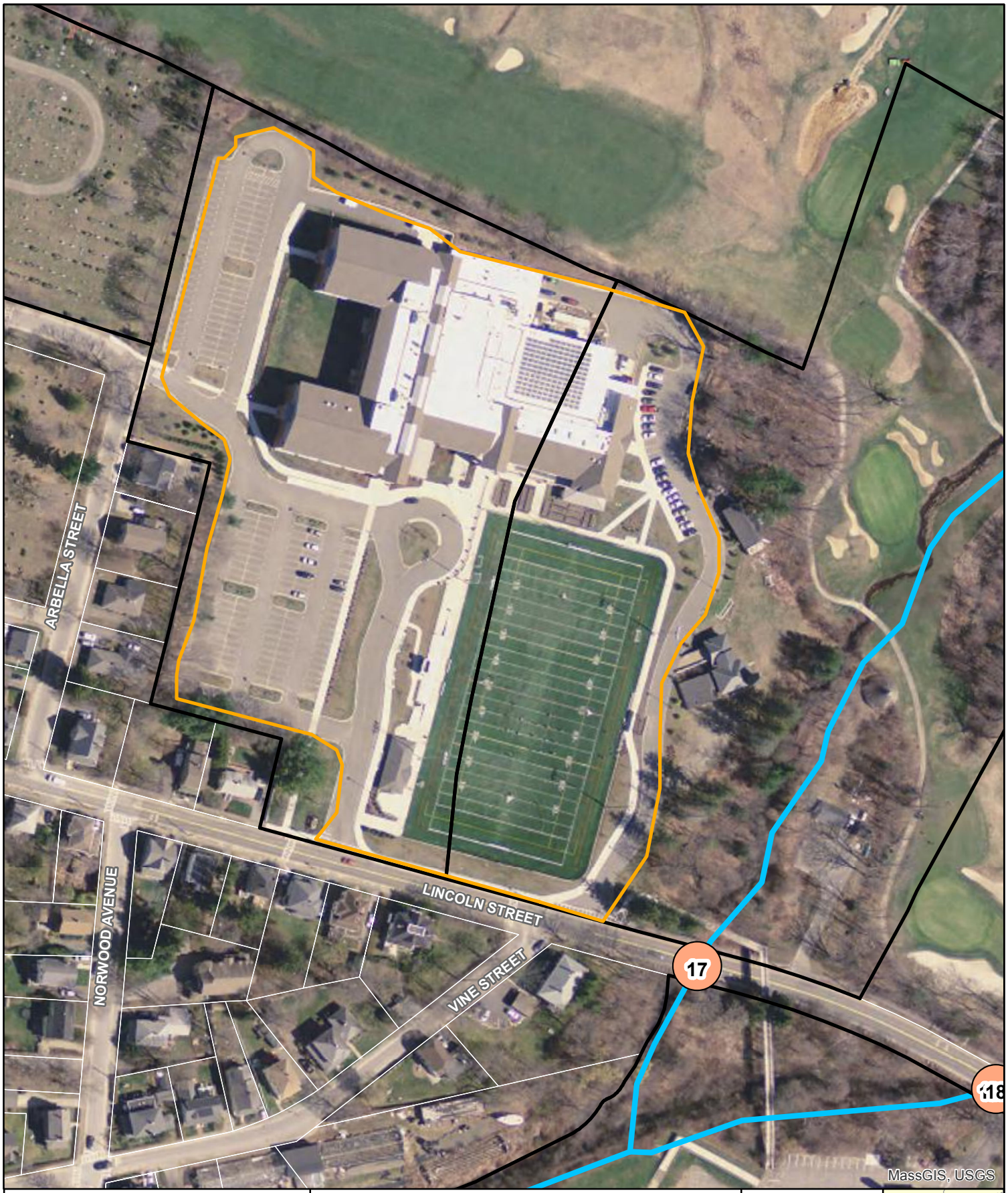
Figure 15 View of main parking area at the High School

Additional Assessment Recommendations

- Site-specific subsurface investigation including geotechnical evaluation and depth to groundwater
- Identification of utilities
- Survey of site including identification of trees

Probable Permits

- Local permits as needed, including tree removal



LEGEND

Culvert

Municipal Parcel

Potential Work Area

SITE 7
HIGHSCHOOL
Manchester-by-the-Sea, MA

Figure 16

Tighe&Bond
Consulting Engineers
Environmental Specialists

0 15
Feet
1 " = 150 '

NOTES

Data sources: Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

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Site 8: Elementary School

Summary

Site 8 includes the parking area at the elementary school. Figures 17 and 18 show the current parking conditions at the school. Projects include potential opportunities to install porous pavement and/or LID BMPs to control stormwater runoff volumes and manage runoff quality. Figure 19 shows the site overview and local conditions.

Figure 17 Parking overflow on grasses area

Figure 18 Driveway pavement conditions

Additional Assessment Needs

- Site-specific subsurface investigation including geotechnical evaluation and depth to groundwater
- Identification of utilities
- Survey of site including identification of trees

Probable Permits

- Construction General Permit (assuming over 1 acre disturbance)
- Order of Conditions from Manchester-by-the-Sea Conservation Commission
- MEPA Environmental Notification Form (depending on final project extent)
- Local permits as needed

LEGEND

Culvert

Municipal Parcel

Potential Work Area

SITE 8
ELEMENTARY SCHOOL
Manchester-by-the-Sea, MA

Figure 19

Tighe&Bond
Consulting Engineers
Environmental Specialists

0 10
Feet
1 " = 100 '

NOTES

Data sources: Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

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Site 9: Golf Course

Summary

Site 9 was selected due to opportunities to manage flooding in the municipally owned land on the Essex Country Club or on the privately owned portion. Figure 20 shows a representative area of the flood plain on the golf course and Figure 21 shows the site and local conditions. Projects would include increasing flood storage areas abutting the stream channel by generally increasing the cross sectional area of the waterbody. In addition, restoring the channel to a more natural orientation would improve aesthetics. Improvements to this location would require coordination with the golf course and considerations for public safety.

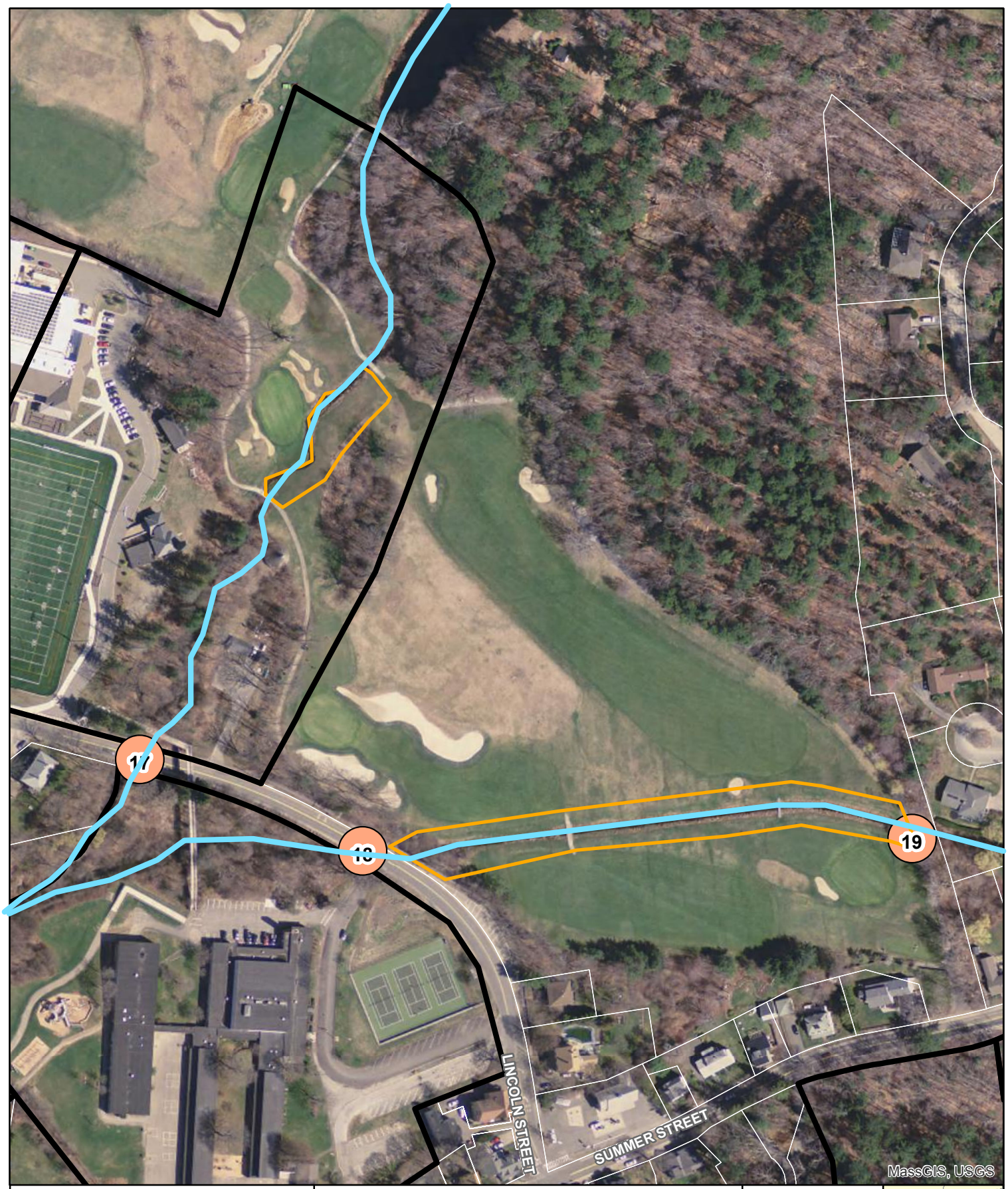
Fig 20 Essex Country Club flood plain area

Additional Assessment Needs

- Coordination with golf course
- Survey including wetlands flagging
- Identification of utilities (if any)
- Hydrologic and hydraulic model to understand potential upstream and downstream impacts

Probable Permits

- Order of Conditions from Manchester-by-the-Sea Conservation Commission
- 401 Water Quality Certificate (depending on amount of material in stream channel removed)
- MEPA Environmental Notification Form (depending on extent of final project)
- Local permits as needed



LEGEND

Culvert

Municipal Parcel

Potential Work Area

SITE 9
GOLF COURSE
Manchester-by-the-Sea, MA

Figure 21

Tighe&Bond
Consulting Engineers
Environmental Specialists

0 20
Feet
1 " = 200 '

NOTES

Data sources: Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

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Site 15: Culvert 2

Summary of Conditions

Site 15 includes the areas around Culvert #2 abutting Town Conservation Land. There may be opportunity to raise the elevation of an abandoned road and resize culverts including installation of flood control device (e.g. weir) to detain upstream water for flood storage. Project should include assessment of need to remove or resize culverts and include outlet control. This would offer a significant area for flood control. Figure 22 shows the site area and local conditions.

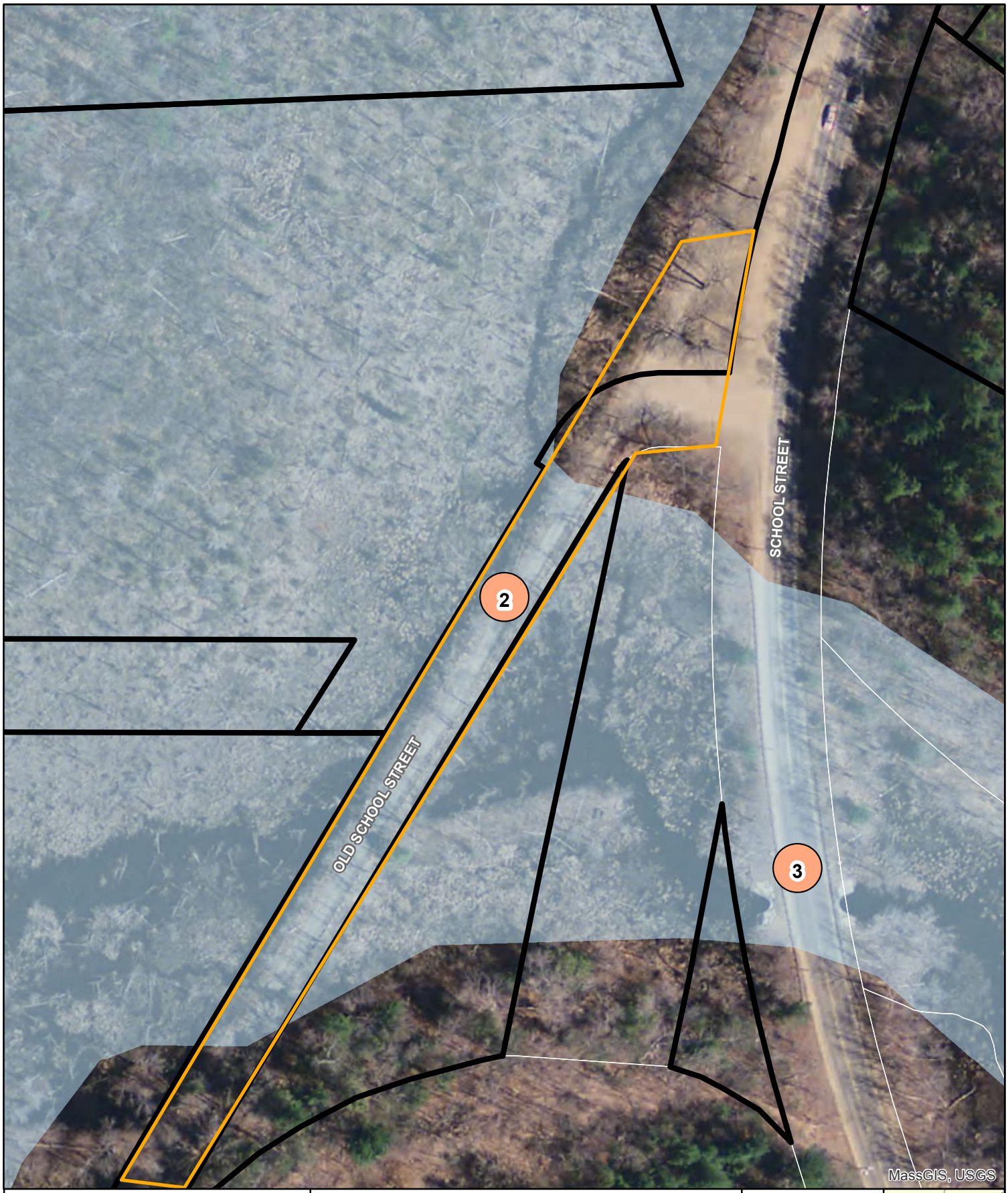
Figure 21 Volunteer at culvert #2

Additional Assessment Conditions

- Survey including wetlands flagging
- Identification of utilities (if any)
- Discussions with Town Conservation Agent and MassDEP about potential use of wetlands as flood storage

Probable Permits

- Order of Conditions from Manchester-by-the-Sea Conservation Commission
- 401 Water Quality Certificate (depending on amount of material in stream channel removed)
- MEPA Environmental Notification Form
- Local permits as needed, including tree removal



LEGEND

Culvert

Municipal Parcel

General Wetlands Area

Potential Work Area

SITE 15
OLD SCHOOL STREET
Manchester-by-the-Sea, MA

Figure 22

Tighe&Bond
Consulting Engineers
Environmental Specialists

0 10
Feet
1 " = 100 '

NOTES

Data sources: Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

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5.1 Downtown Area Improvement Projects

The concurrent Downtown Improvements Project Phase 2 identified corridors in the downtown Manchester-by-the-Sea Phase 2 Study Area that are feasible for installation of LID BMPs. The Study Area extends along Central Street from Pine Street to Beach Street and includes the municipal parking area south of Town Hall (Figure 23). This area is highly developed and is composed of a mix of commercial and residential areas with extensive impervious cover. A summary of that effort is provided here to bring the other watershed projects into context with potential downtown improvement projects.

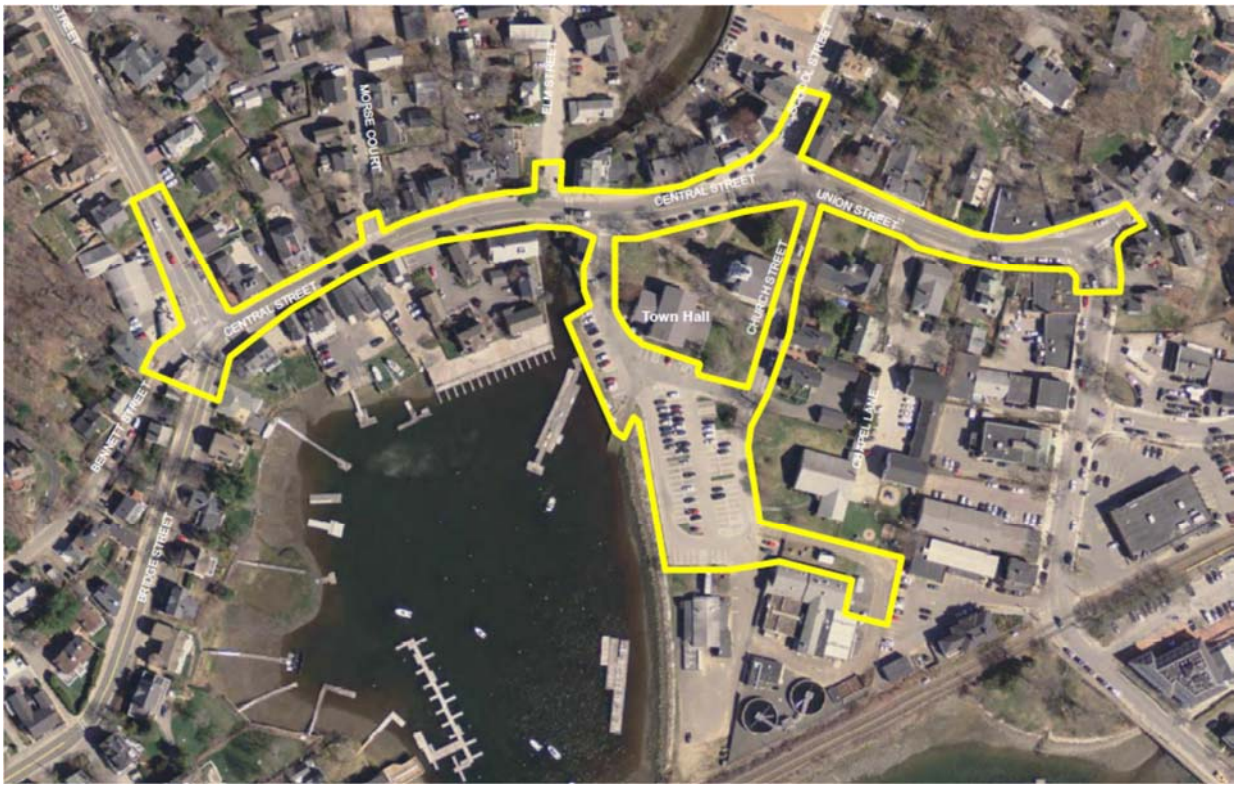


Figure 23 Outline of the Phase 2 Downtown Improvement Area

A number of Low Impact Development (LID) Stormwater Best Management Practices (BMPs) were considered for use in the downtown area to reduce stormwater runoff volumes and rates, and decrease pollutant discharges to Sawmill Brook and the Harbor. LID BMPs in the following categories were evaluated:

- Porous Pavement;
- Tree Pits; and
- Roadway BMPs.

The following LID BMP alternatives were recommended for further consideration in the Study Area and were used in the Conceptual Design Phase of the study:

- Porous Asphalt
- Porous Pavers
- Tree Pit (the concept design is based on the Filterra ®)
- Modular Wetlands
- Rain Garden
- Tree Trench (aka Rain Garden)

- Structural Filter (the concept design was based on the Jellyfish Filter ®)

To allow greater flexibility for design and construction, Tighe & Bond worked with the Downtown Improvement Committee to divide the Study Area into "corridors" based on types of BMPs that can be used in the space. These corridors include a Limited Right-of-Way Corridor, a Flexible Right-of-Way Corridor, and a Municipal Parking Lot. The Limited Right-of-Way Corridor has a narrower roadway and sidewalk width and varies from approximately 36-50 feet wide which results in less available space for installation of BMPs, while the Flexible Right of Corridor is wider (approximately 40-58 feet) and provides more opportunities for installation of larger LID BMPs (e.g. tree trench) as well as the ability to accommodate parallel parking along the roadway.

Tighe & Bond prepared conceptual designs for the LID BMPs identified as most feasible for use within each corridor.

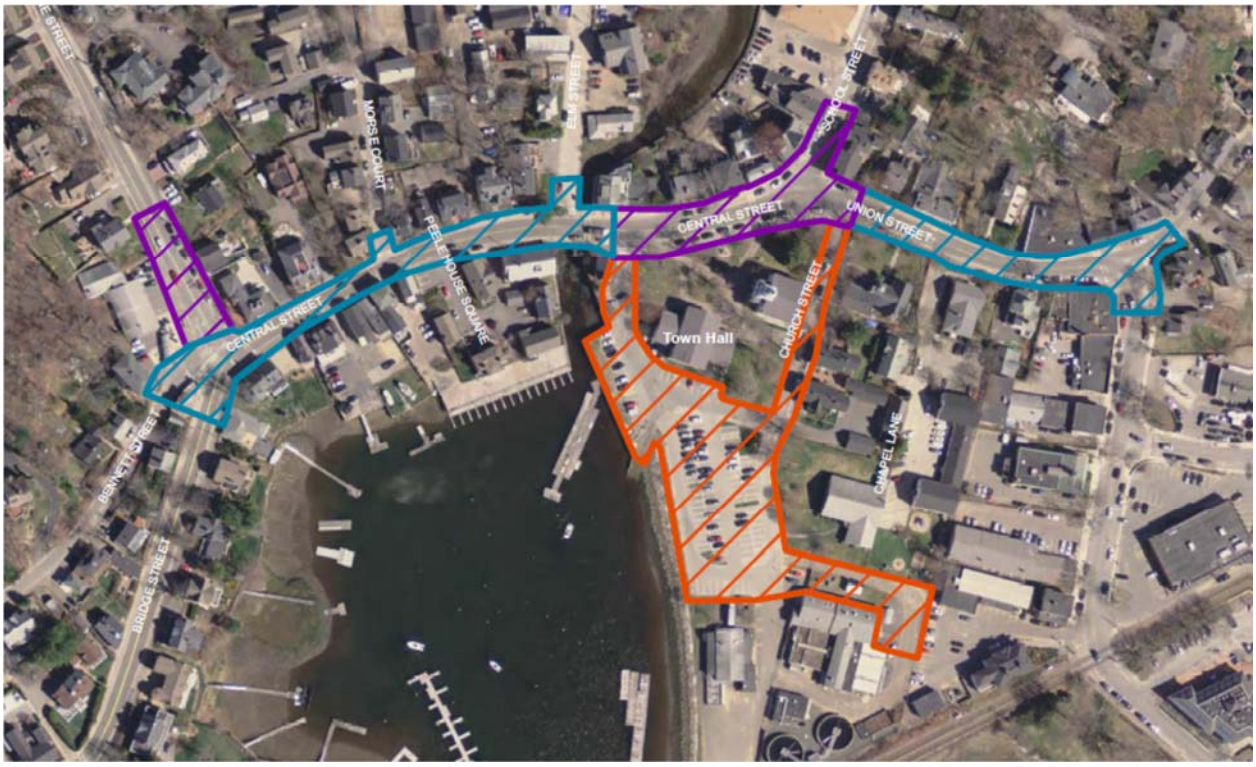
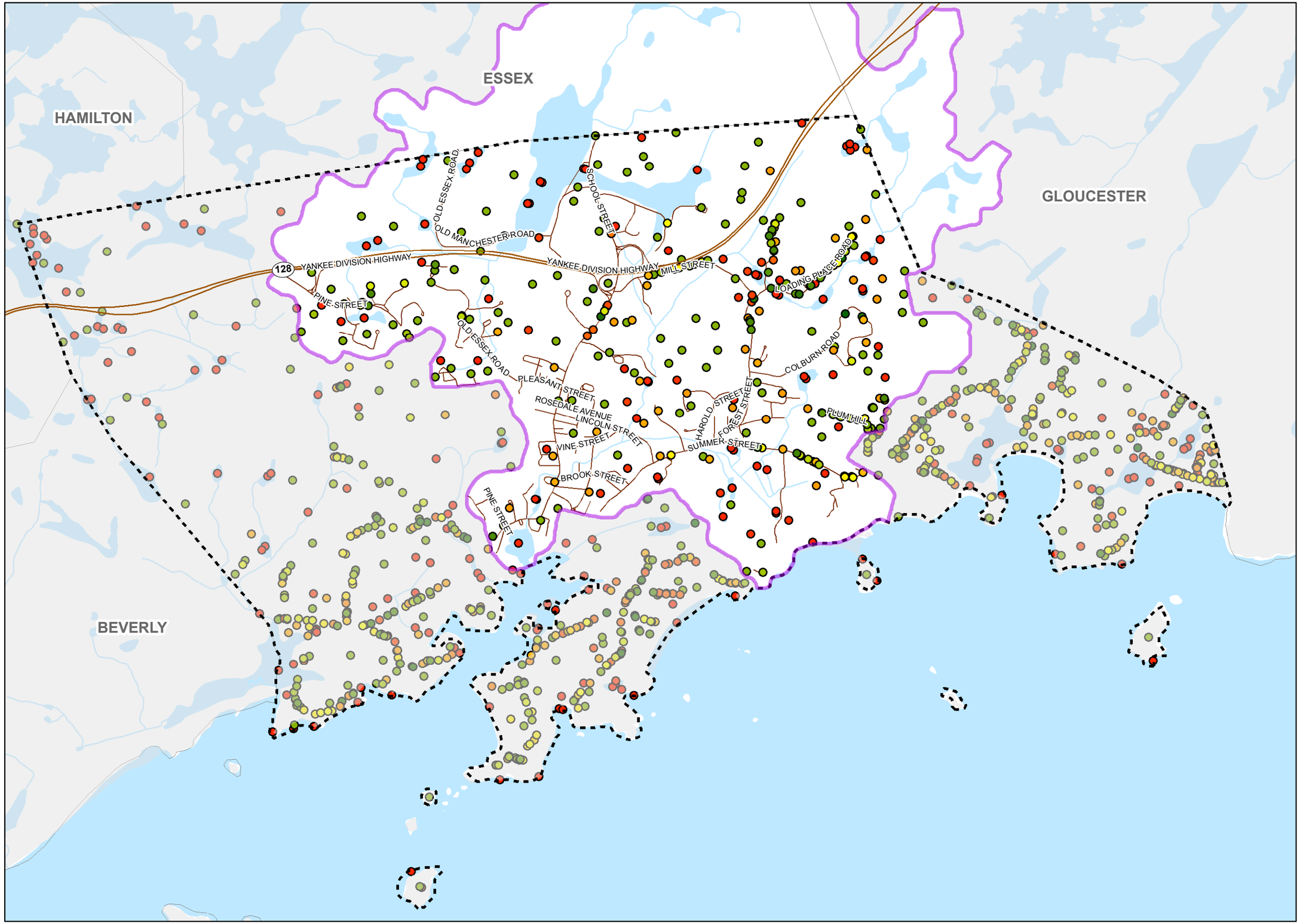


Figure 24 Defined extent of BMP corridors in Phase 2 Downtown Improvement areas

Tighe&Bond

APPENDIX A



DESKTOP EVALUATION FIGURE A1 DEPTH TO GROUNDWATER (DATA)

LEGEND

- Roads
- Sawmill Brook Watershed
- Water Body
- Manchester by the Sea
- TownBoundary

Depth to Groundwater Points

- Deep
- Shallow

LOCUS MAP

N

0 500 1,000 2,000

Feet

1:24,000

1 inch = 2,000 feet

NOTES

Based on MassDEP Well Drilling Database, NRCS SSURGO- Certified Soils (Nov. 2012), USDA NRCS Custom Soil Resource Report for Essex County Southern Part, Town of Manchester-by-the-Sea 2014 Septic System Database, and MassDEP Hydrography (1:25,000)

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Manchester-by-the-Sea, MA

May 2015

Tighe&Bond
Consulting Engineers
Environmental Specialists

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DESKTOP EVALUATION
FIGURE A1
DEPTH TO GROUNDWATER (RESULT)

ESSEX
HAMILTON
GLOUCESTER
WENHAM
BEVERLY
128
OLD ESSEX ROAD
OLD MANCHESTER ROAD
SCHOOL STREET
YANKEE DIVISION HIGHWAY
YANKEE DIVISION HIGHWAY
MILL STREET
LOADING PLACE ROAD
PINE STREET
OLD ESSEX ROAD
PLEASANT STREET
ROSEDALE AVENUE
LINCOLN STREET
VINE STREET
BROOK STREET
PINE STREET
HAROLD STREET
FOREST STREET
SUMMER STREET
COLBURN ROAD
PLUM HILL

LEGEND

- Roads
- Sawmill Brook Watershed
- Water Body
- Manchester by the Sea
- TownBoundary

Depth to Groundwater

- Deep
- Shallow

LOCUS MAP

N

0 500 1,000 2,000

Feet

1:24,000

1 in = 2,000 ft

NOTES

Based on MassDEP Well Drilling Database, NRCS SSURGO- Certified Soils (Nov. 2012), USDA NRCS Custom Soil Resource Report for Essex County Southern Part, Town of Manchester-by-the-Sea 2014 Septic System Database, and MassDEP Hydrography (1:25,000)

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DESKTOP EVALUATION
FIGURE A2
SLOPE OF SURFACE

ESSEX
HAMILTON
GLOUCESTER
WENHAM
BEVERLY
128
YANKEE DIVISION HIGHWAY
OLD ESSEX ROAD
OLD MANCHESTER ROAD
SCHOOL STREET
MILL STREET
LOADING PLACE ROAD
PINE STREET
COLBURN ROAD
PLEASANT STREET
ROSEDALE AVENUE
LINCOLN STREET
HAROLD STREET
FOREST STREET
PLUM HILL
VINE STREET
SUMMER STREET
BROOK STREET

LEGEND

- Roads
- Sawmill Brook Watershed
- Water Body
- Manchester by the Sea
- TownBoundary

Percent Slope

- 0-5% (5)
- 5-10% (3)
- >10% (1)

LOCUS MAP

N

0 500 1,000 2,000
Feet

1:24,000
1 in = 2,000 ft

NOTES

Based on 2011 LiDAR for Northeast available through MassGIS

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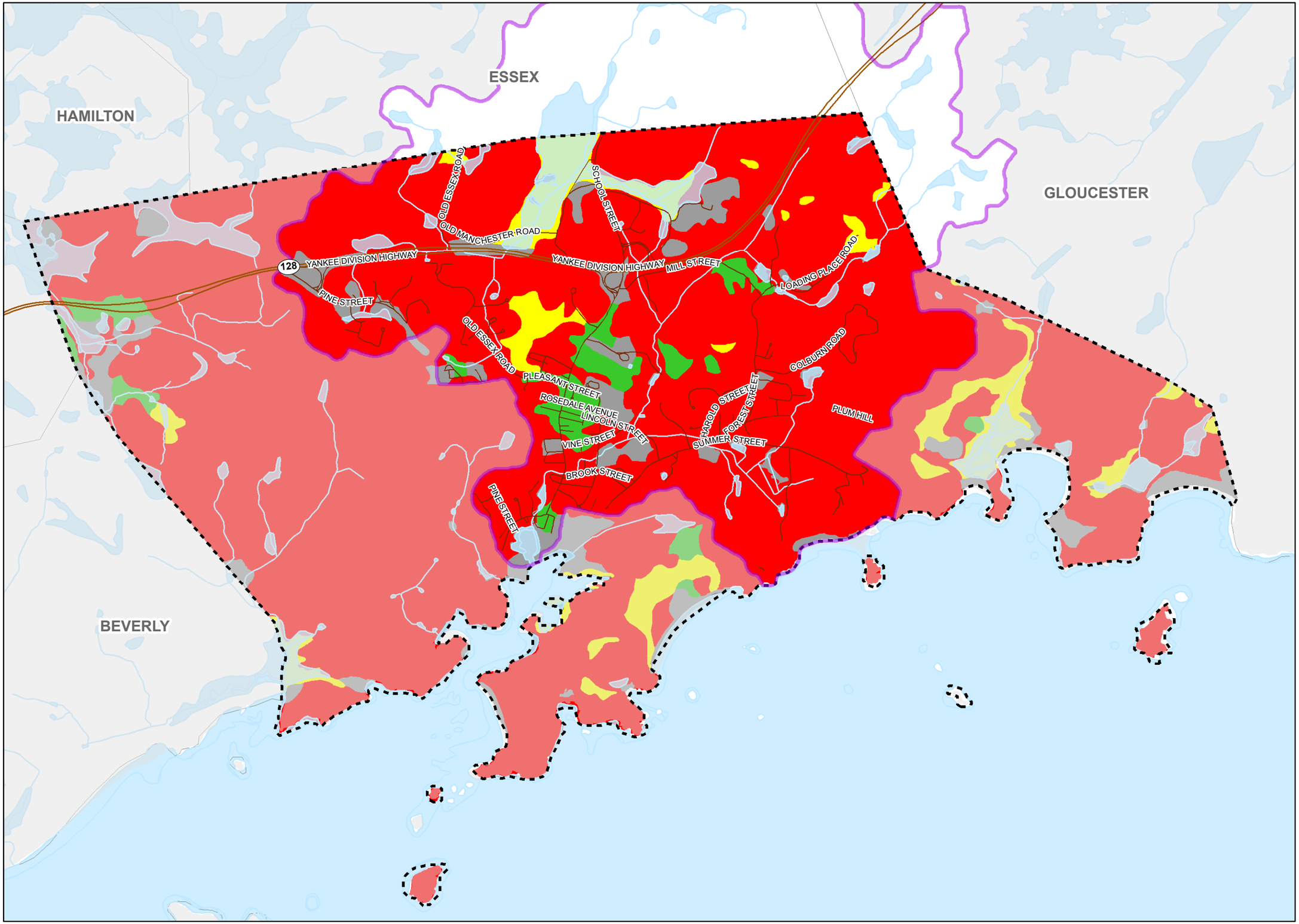

DESKTOP EVALUATION FIGURE A3 SOIL PERMEABILITY

LEGEND

- Roads
- Sawmill Brook Watershed
- Water Body
- Manchester by the Sea
- TownBoundary

Permeability Rating

- Rapid (>20 in/hr) (5)
- Moderately Rapid (6 to 20 in/hr) (3)
- Very Slow to Moderate (<6 in/hr) (1)
- Beaches, Pits, Gravel, Udorthents, & Urban Land (0)

LOCUS MAP

N

0 500 1,000 2,000

Feet

1:24,000

1 in = 2,000 ft

NOTES

Based on NRCS SSURGO-Certified Soils (Nov. 2012) and USDA NRCS Custom Soil Resource Report for Essex County Southern Part

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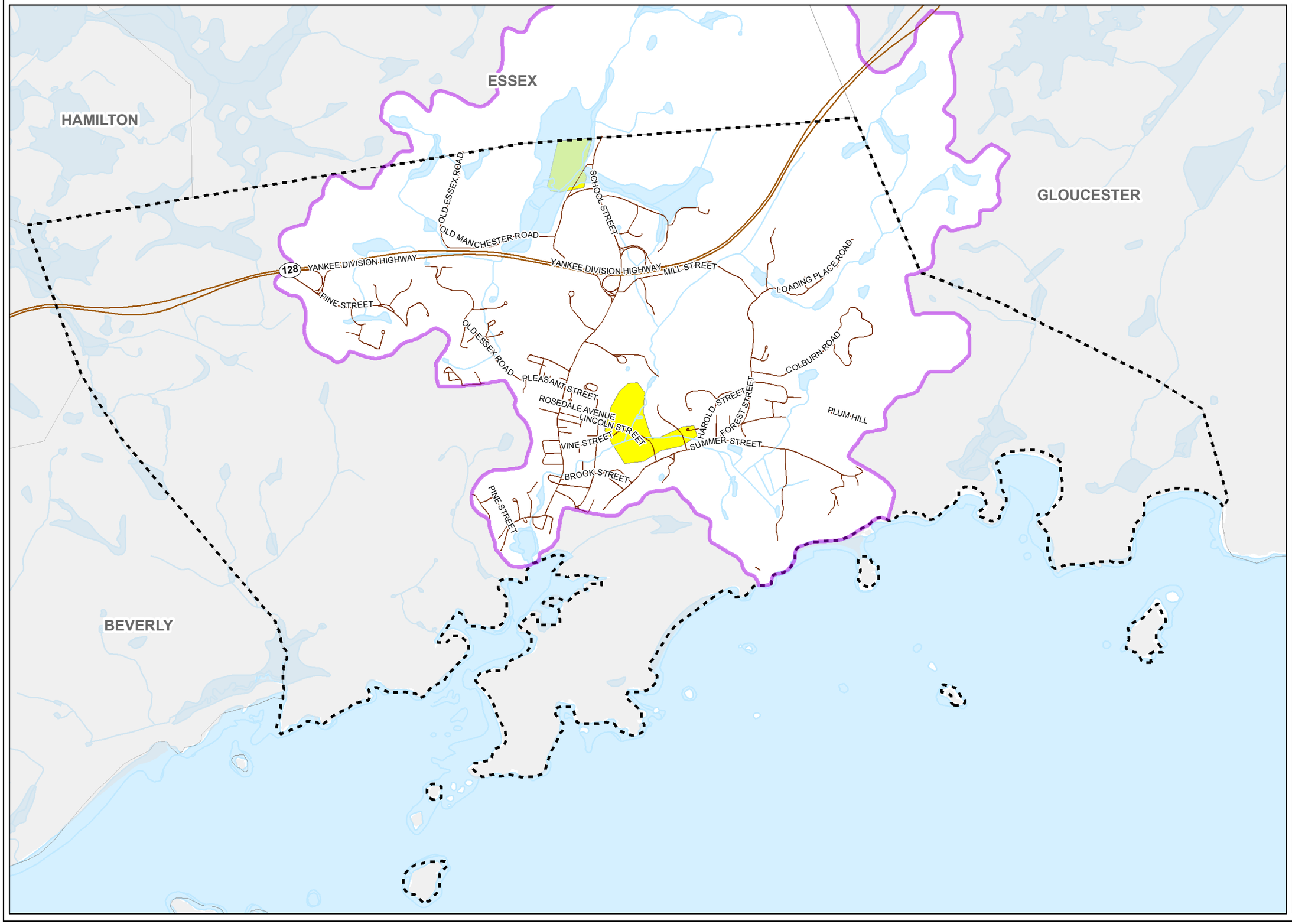
DESKTOP EVALUATION
FIGURE A4
TRANSMISSIVITY



LEGEND

- Roads
- Sawmill Brook Watershed
- Water Body
- Manchester by the Sea
- TownBoundary
- Transmissivity - 1,400 to 4,000 sq.ft./day (3)

LOCUS MAP

N

0 500 1,000 2,000

Feet

1:24,000

1 in = 2,000 ft

NOTES

Based on MassDEP Aquifers datalayer (July 2007)

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Path: G:\GIS\MA\ManchesterMA\GreenInfrastructure\MapDocuments\Figures\A4_Transmissivity.mxd

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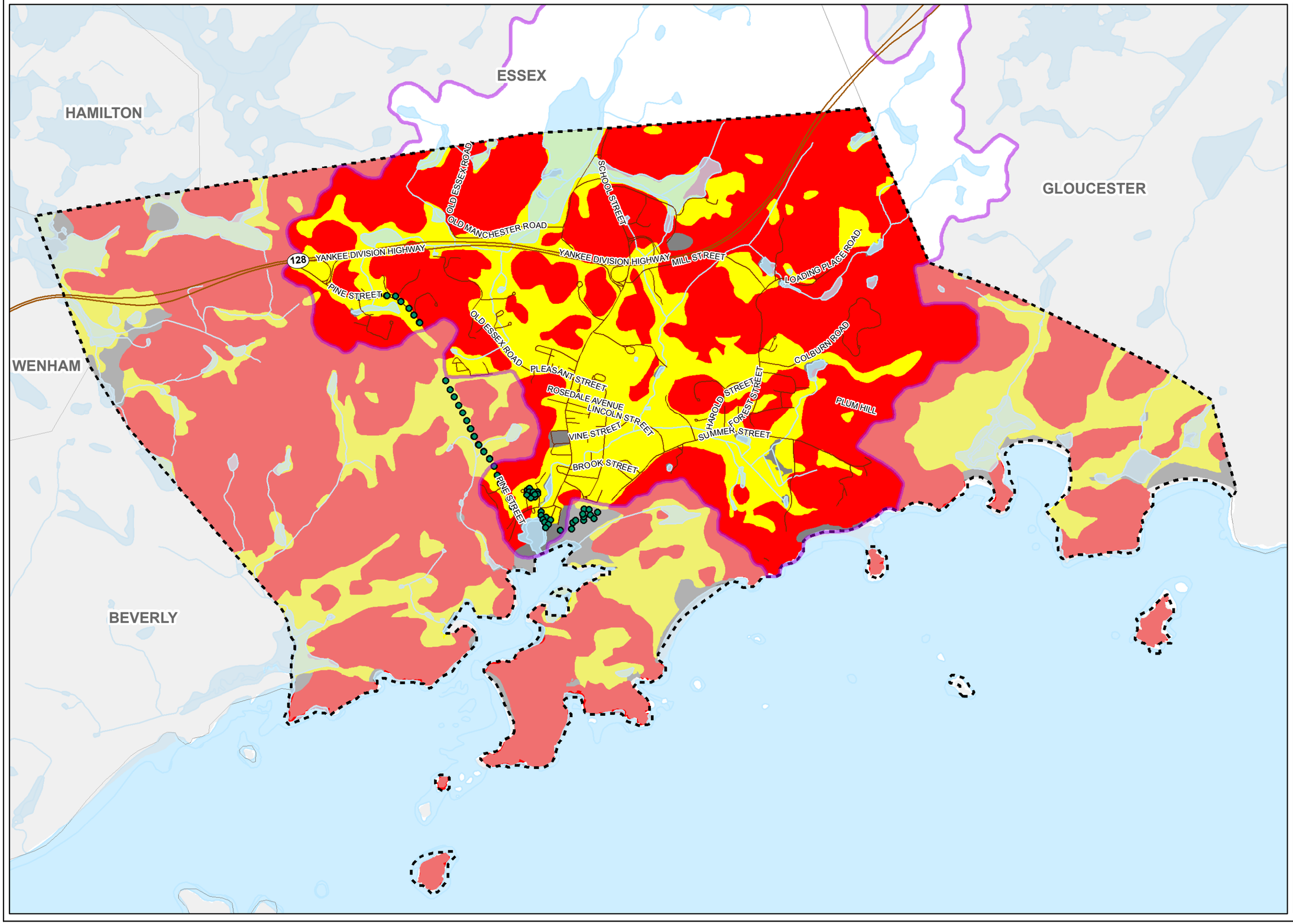
DESKTOP EVALUATION
FIGURE A5
DEPTH TO BEDROCK



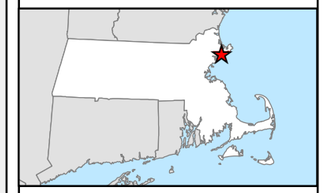
LEGEND

- Borings from Previous Projects
- Roads
- Sawmill Brook Watershed
- Water Body
- Manchester by the Sea
- TownBoundary

Depth to Bedrock

- Water, Gravel, Pit, Urban Land, Beach (0)
- Not Feasible, 0-5ft (1)
- Low, 5-10ft (3)

LOCUS MAP



N

0 500 1,000 2,000

Feet

1:24,000

1 in = 2,000 ft

NOTES

Based on NRCS SSURGO-Certified Soils (Nov. 2012), USDA NRCS Custom Soil Resource Report for Essex County Southern Part, and Borings from other Town Projects

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DESKTOP EVALUATION
FIGURE A6
INITIAL SITE SCORING

LEGEND

- Sawmill Brook Watershed
- Water Body
- Manchester by the Sea
- Town Owned Property
- Parcels
- Roads

10' x10' Grid Cells
Total_1

17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2

LOCUS MAP

0 0.25 0.5
Miles

1:12,000

NOTES

Sawmill Brook Culvert &
Green Infrastructure Analysis
Manchester-by-the-Sea, MA

May 2015

Tighe&Bond

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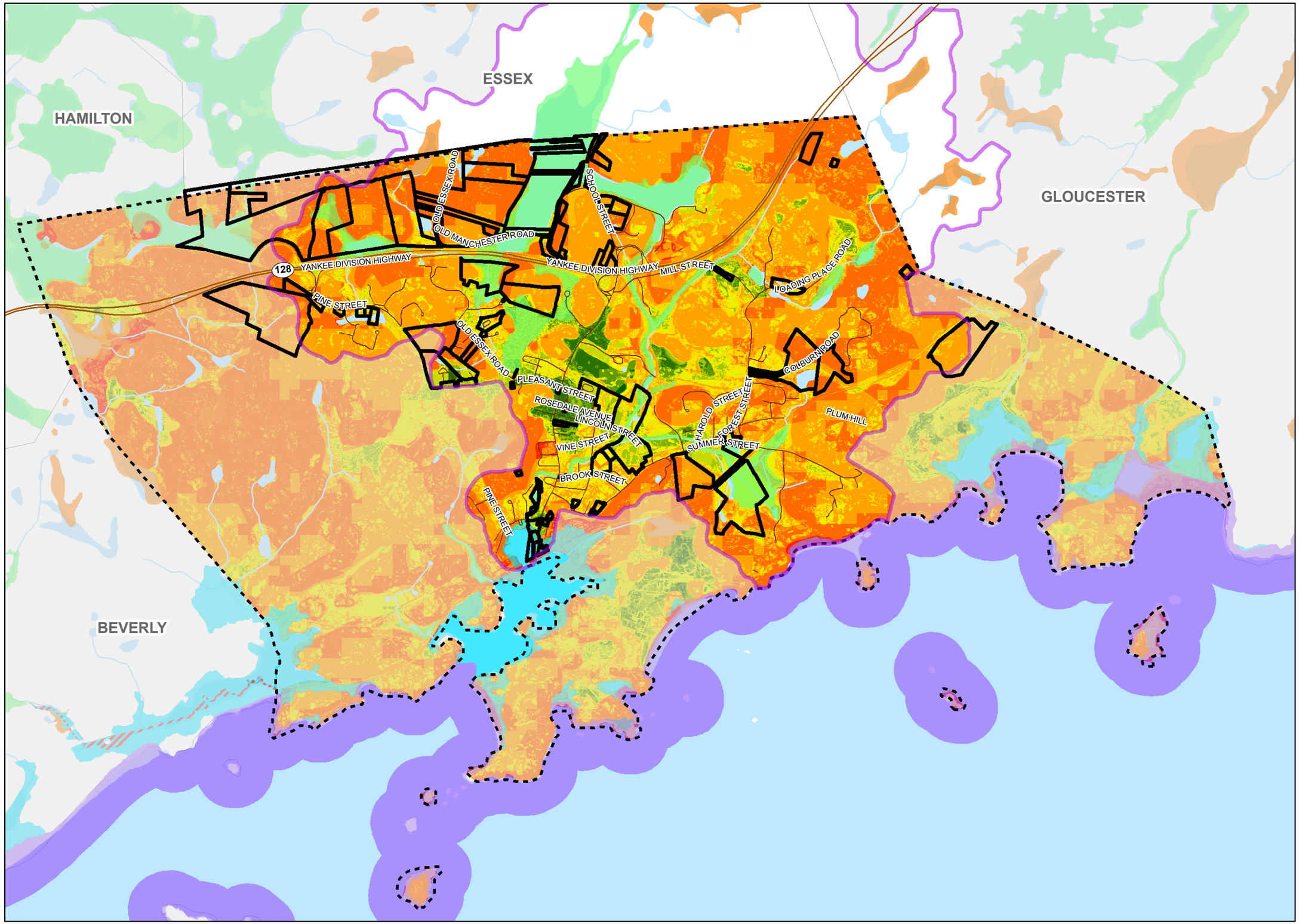
DESKTOP EVALUATION
FIGURE A7
FEMA FLOOD ZONES



LEGEND

- Roads
- Sawmill Brook Watershed
- Municipal Parcel
- Water Body
- Manchester by the Sea
- TownBoundary

FEMA National Flood Hazard Layer

- A: 1% Annual Chance of Flooding, no BFE
- AE: 1% Annual Chance of Flooding, with BFE
- AE: Regulatory Floodway
- AO: 1% Annual Chance of 1-3ft Sheet Flow Flooding, with Depth
- VE: High Risk Coastal Area
- X: 0.2% Annual Chance of Flooding

10' x10' Grid Cells
Total_1

17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2

LOCUS MAP

N

0 500 1,000 2,000
Feet
1:24,000
1 inch = 2,000 feet

NOTES

Based on MassGIS 2014 FEMA Flood Data.

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Manchester-by-the-Sea, MA

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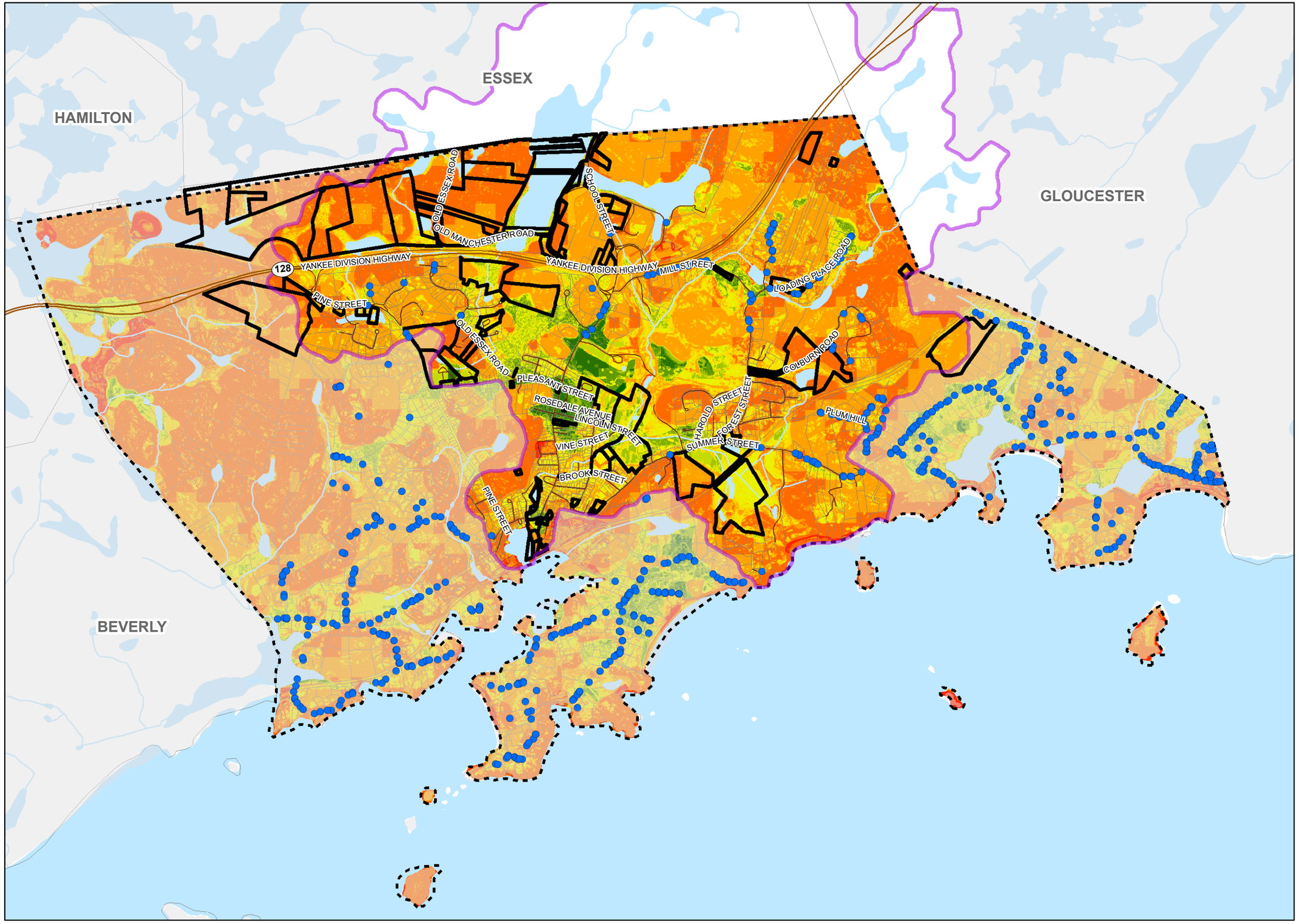
DESKTOP EVALUATION
FIGURE A8
SEPTIC SYSTEMS



LEGEND

- Roads
- Sawmill Brook Watershed
- Municipal Parcel
- Approximate Location of Parcel With Septic System
- Water Body
- Parcels
- Manchester by the Sea
- TownBoundary

10' x10' Grid Cells
Total_1

17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2

LOCUS MAP

N

0 500 1,000 2,000
Feet
1:24,000
1 inch = 2,000 feet

NOTES

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Manchester-by-the-Sea, MA

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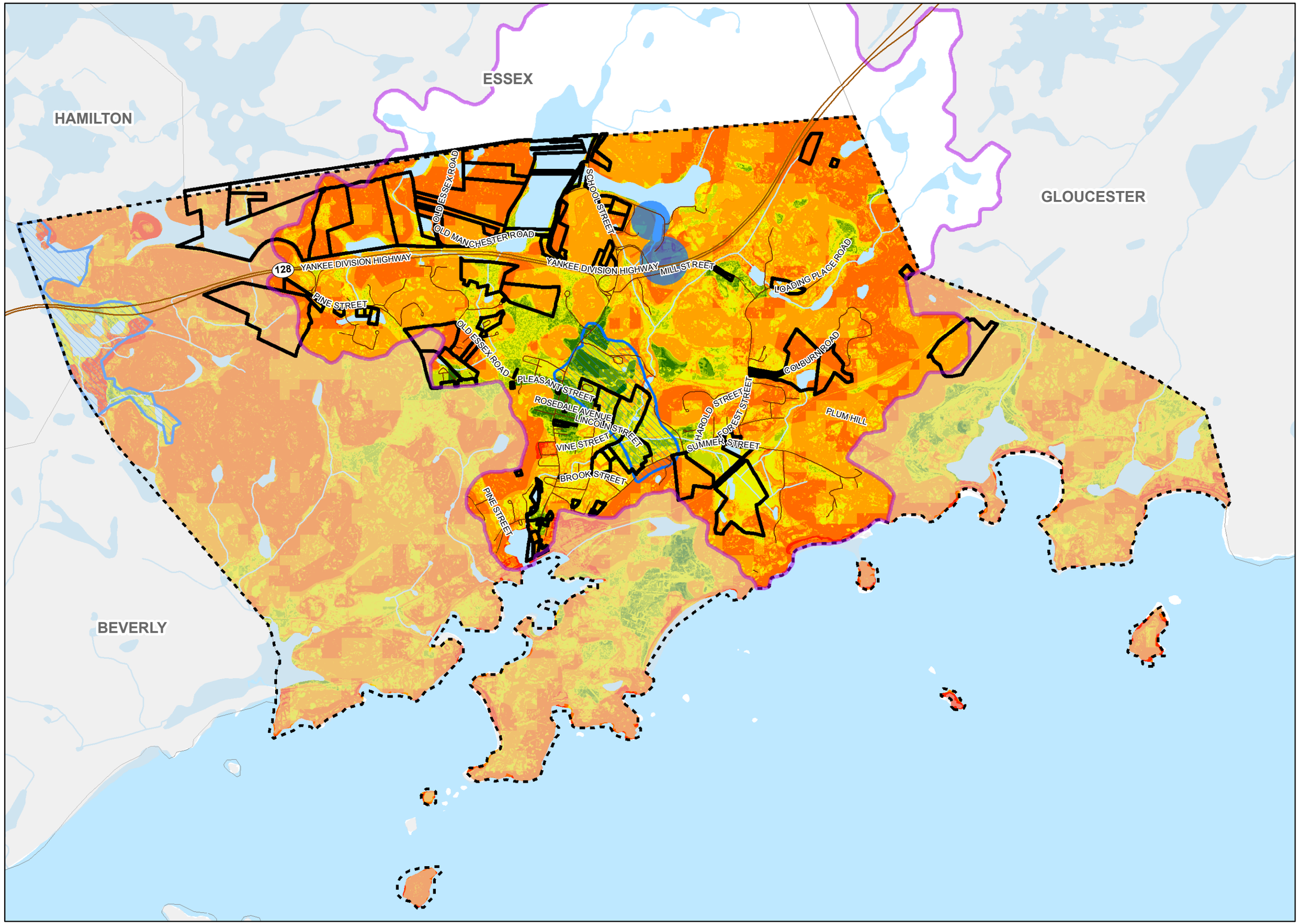
DESKTOP EVALUATION
FIGURE A9
WELLHEAD PROTECTION AREAS



LEGEND

- Roads
- Sawmill Brook Watershed
- Municipal Parcel
- Water Body
- Manchester by the Sea TownBoundary
- DEP Interim Wellhead Protection Area (IWPA)
- DEP Approved Wellhead Protection Area (Zone II)

10' x10' Grid Cells
Total_1

17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2

LOCUS MAP

N

0 500 1,000 2,000
Feet
1:24,000
1 inch = 2,000 feet

NOTES

Sawmill Brook Culvert & Green Infrastructure Analysis
Manchester-by-the-Sea, MA

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Environmental Specialists

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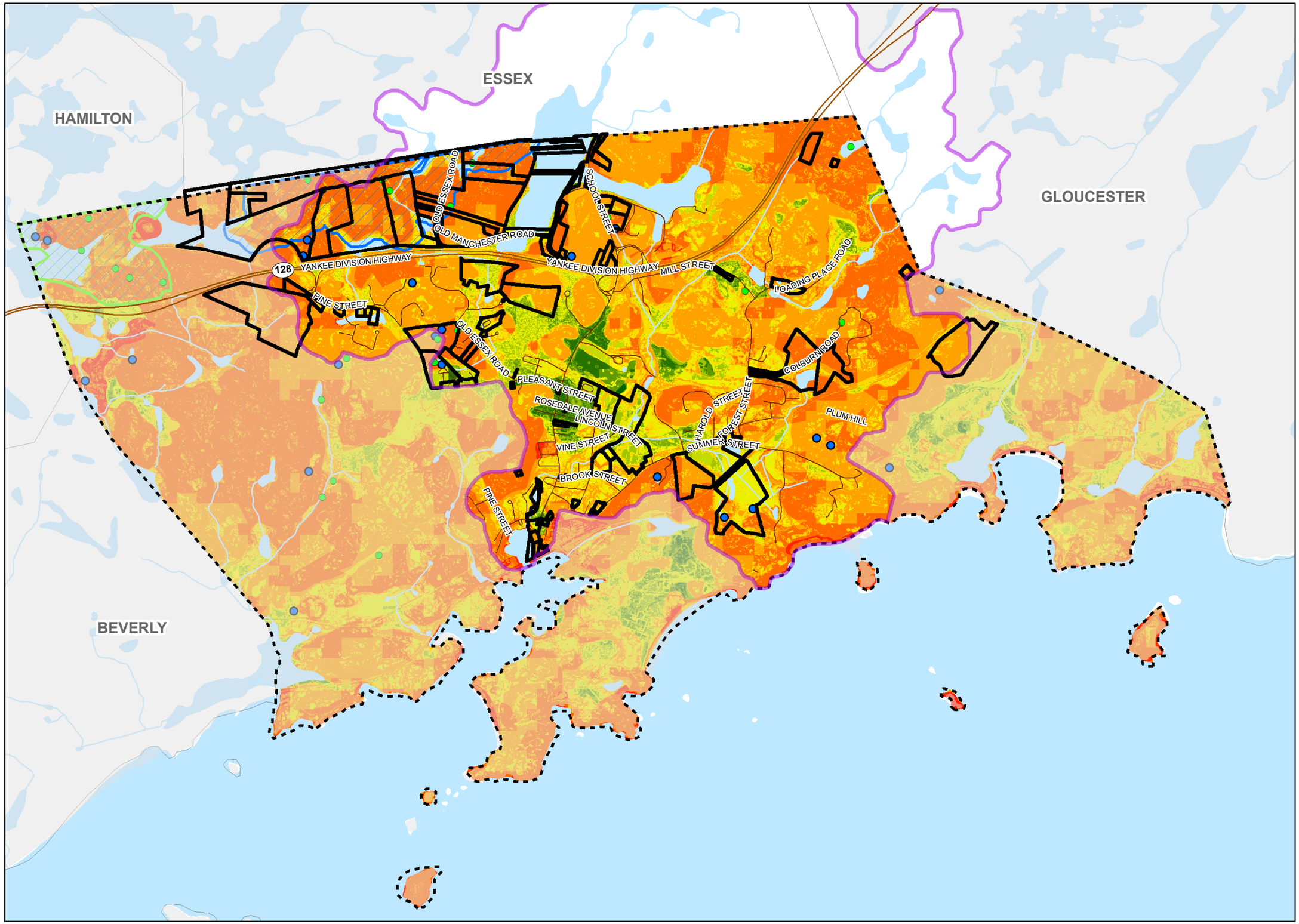
DESKTOP EVALUATION
FIGURE A10
NHESP



LEGEND

- Roads
- Sawmill Brook Watershed
- Water Body
- Municipal Parcel
- Manchester by the Sea
- TownBoundary
- NHESP Potential Vernal Pools
- NHESP Certified Vernal Pools
- NHESP Priority Habitats for Rare Species
- NHESP Estimated Habitats for Rare Wildlife

10' x10' Grid Cells
Total_1

17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2

LOCUS MAP

N

0 500 1,000 2,000
Feet
1:24,000
1 inch = 2,000 feet

NOTES

Sawmill Brook Culvert & Green Infrastructure Analysis
Manchester-by-the-Sea, MA

May 2015

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Path: G:\GIS\MA\ManchesterMA\GreenInfrastructure\MapDocuments\Figures\A10_NHESP.mxd

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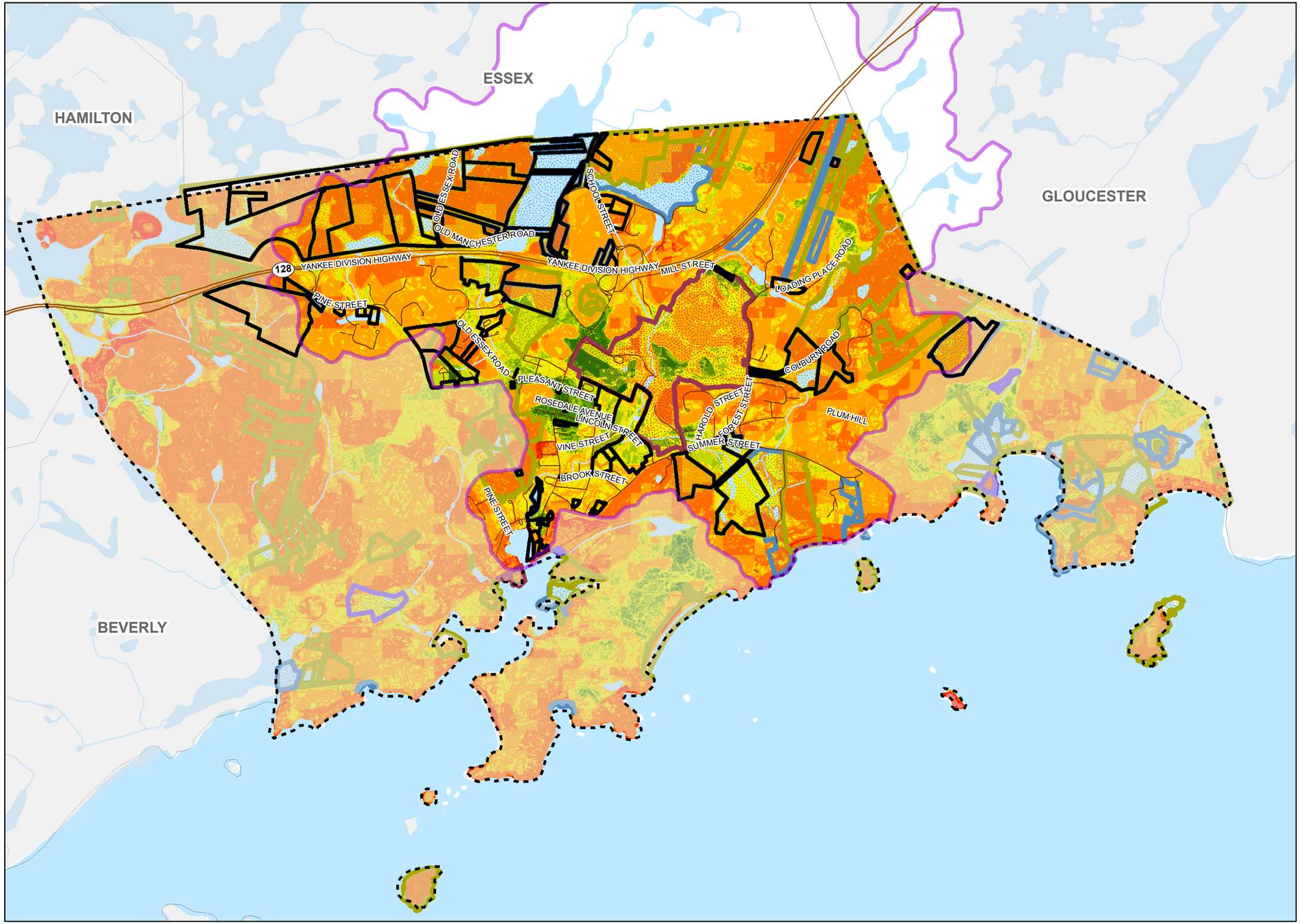
DESKTOP EVALUATION FIGURE A11 PROTECTED OPEN SPACE



LEGEND

- Roads
- Sawmill Brook Watershed
- Municipal Parcel
- Water Body
- Manchester by the Sea
- TownBoundary

Open Space: Level of Protection

- In Perpetuity
- Limited
- None
- Unknown

10' x10' Grid Cells
Total_1

17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2

LOCUS MAP

N

0 500 1,000 2,000

Feet

1:24,000

1 inch = 2,000 feet

NOTES

Sawmill Brook Culvert & Green Infrastructure Analysis
Manchester-by-the-Sea, MA

May 2015

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Environmental Specialists

Path: G:\GIS\MA\ManchesterMA\GreenInfrastructure\MapDocuments\Figures\A11_OpenSpace.mxd

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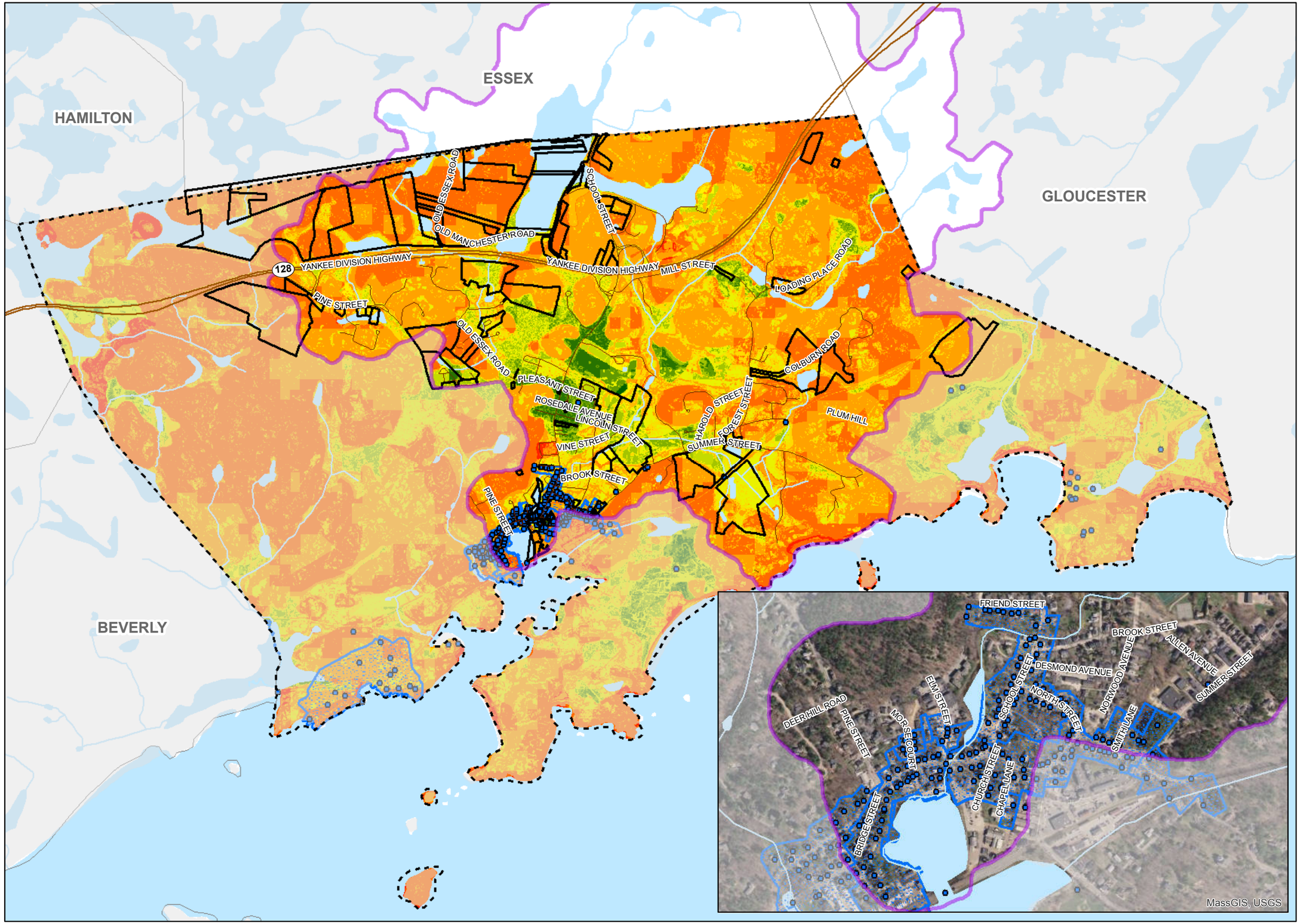
DESKTOP EVALUATION
FIGURE A12
MASS HISTORICAL COMMISION SITES



LEGEND

- Roads
- Sawmill Brook Watershed
- Municipal Parcel
- Water Body
- Manchester by the Sea
- TownBoundary
- MHC Point
- MHC District

10' x10' Grid Cells
Total_1

17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2

LOCUS MAP

0 500 1,000 2,000
Feet
1:24,000
1 inch = 2,000 feet

NOTES

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Manchester-by-the-Sea, MA

July 2015

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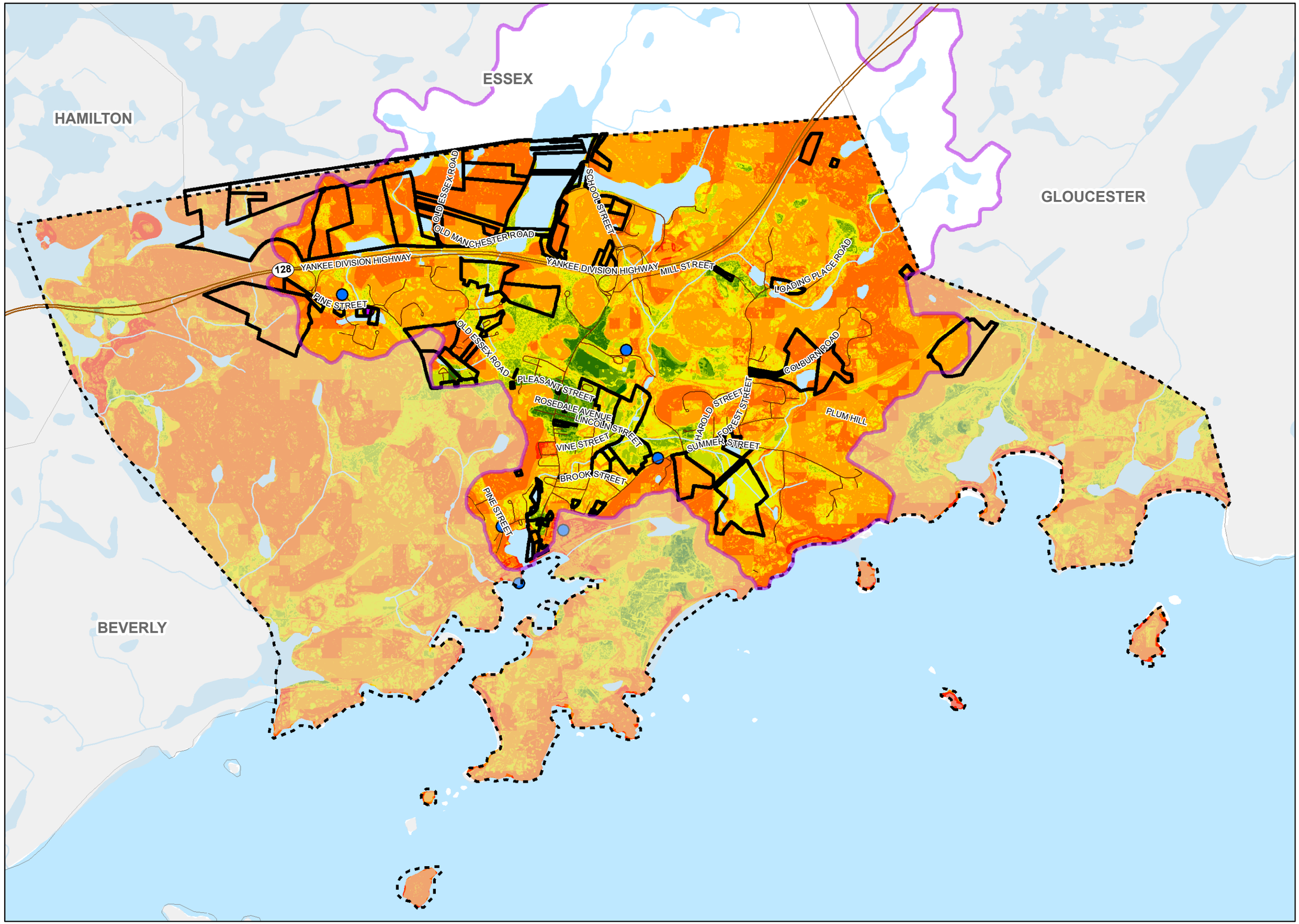
DESKTOP EVALUATION
FIGURE A13
CONTAMINATED SITES



LEGEND

- Roads
- Sawmill Brook Watershed
- Municipal Parcel
- Water Body
- Manchester by the Sea
- TownBoundary
- MassDEP Tier Classified Oil and/or Hazardous Material Sites (MGL c. 21E) Datalayer
- MassDEP Underground Storage Tank
- MassDEP Oil and/or Hazardous Material Sites with Activity and Use Limitations (AUL) Datalayer (None in MBTS)

10' x10' Grid Cells
Total_1

17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2

LOCUS MAP

0 500 1,000 2,000
Feet
1:24,000
1 inch = 2,000 feet

NOTES

Sawmill Brook Culvert & Green Infrastructure Analysis
Manchester-by-the-Sea, MA

May 2015

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Path: G:\GIS\MA\ManchesterMA\GreenInfrastructure\MapDocuments\Figures\A13_ContaminatedSites.mxd

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DESKTOP EVALUATION
FIGURE A14
WETLANDS
JURISDICTION

ESSEX

HAMILTON

GLOUCESTER

BEVERLY

OLD ESSEX ROAD

OLD MANCHESTER ROAD

SCHOOL STREET

128 YANKEE DIVISION HIGHWAY

YANKEE DIVISION HIGHWAY

MILL STREET

LOADING PLACE ROAD

PINE STREET

OLD ESSEX ROAD

PLEASANT STREET

ROSEDALE AVENUE

LINCOLN STREET

VINE STREET

BROOK STREET

PINE STREET

HAROLD STREET

FOREST STREET

SUMMER STREET

COLBURN ROAD

PLUM HILL

LEGEND

	10' x10' Grid Cells Total_1
Roads	
Sawmill Brook Watershed	
Municipal Parcel	17
Water Body	16
Manchester by the Sea	15
TownBoundary	14
100 ft Wetland Buffer	13
200ft Hydrologic Buffer	12
Shoreline	11
Hydrologic Connection	10
Mean Low Water Line	9
Wetland Limit	8
Closure Line	7
Marsh/Bog	6
Wooded marsh	5
Cranberry Bog	4
Salt Marsh	3
Open Water	2
Reservoir (with PWSID)	
Tidal Flats	
Beach/Dune	

LOCUS MAP

N

0 500 1,000 2,000

Feet

1:24,000

1 inch = 2,000 feet

NOTES

Based on MassGIS 2014 FEMA Flood Data.

Sawmill Brook Culvert & Green Infrastructure Analysis
Manchester-by-the-Sea, MA

May 2015

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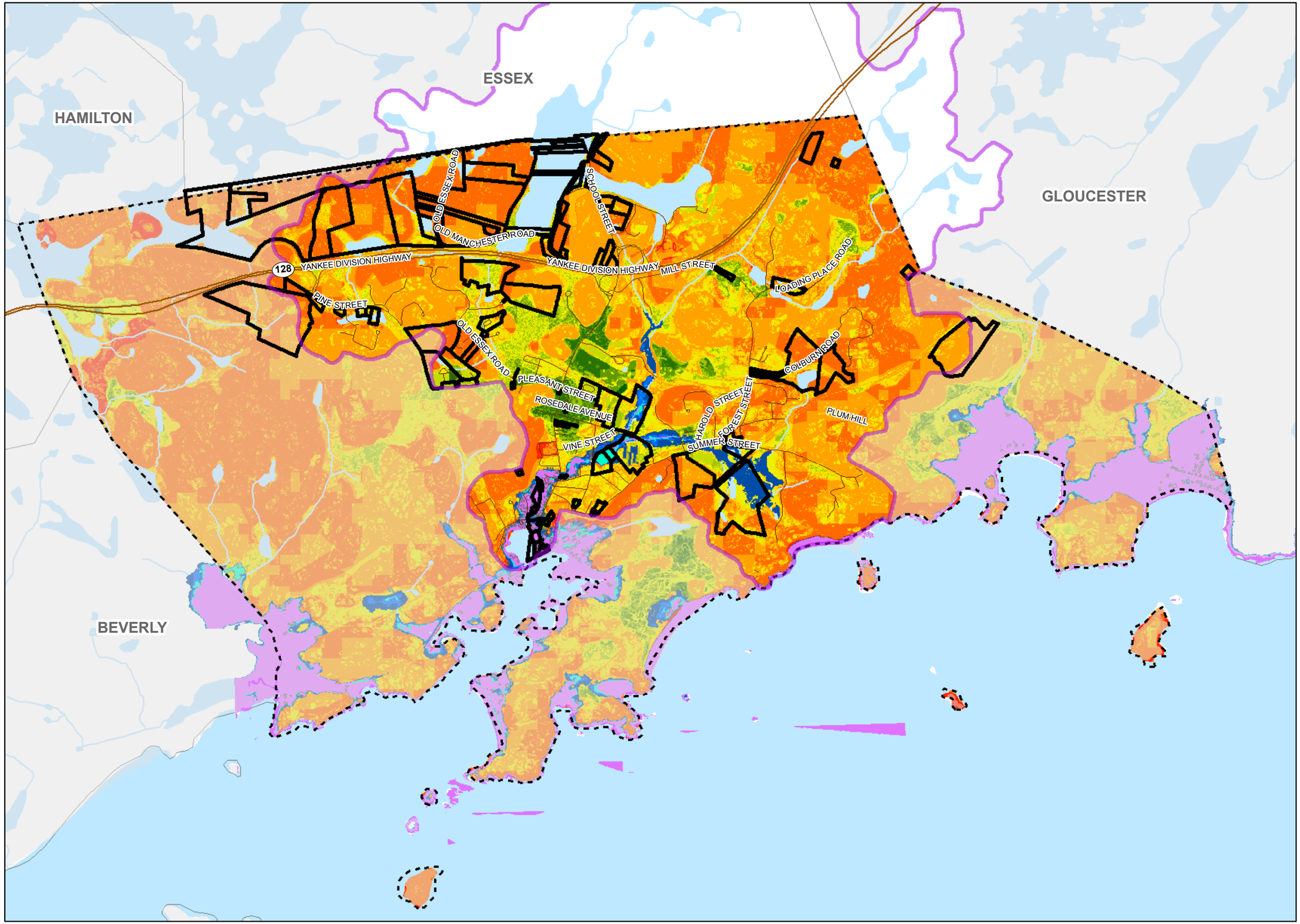
DESKTOP EVALUATION
FIGURE A15
SEA LEVEL RISE
EXPANSION ZONES



LEGEND

- Roads
- Sawmill Brook Watershed
- Municipal Parcel
- Water Body
- Manchester by the Sea
- TownBoundary

Impacted Buildings

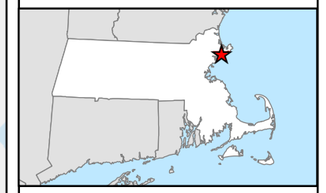
- Adjusted Baseline Floodplain
- 1' Sea Level Rise
- 2' Sea Level Rise
- 4' Sea Level Rise

10' x10' Grid Cells

Total_1

17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2

LOCUS MAP



0 500 1,000 2,000

Feet

1:24,000

1 inch = 2,000 feet

NOTES

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Manchester-by-the-Sea, MA

May 2015

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Environmental Specialists

Path: G:\GIS\MA\ManchesterMA\GreenInfrastructure\MapDocuments\Figures\A15_SeaLevelRise.mxd

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APPENDIX B

SAWMILL BROOK CULVERT AND GREEN INFRASTRUCTURE ANALYSIS
DESKTOP ASSESSMENT

Tighe & Bond is identifying opportunities to mitigate flooding throughout the Sawmill Brook Watershed. Flood mitigation methods to reduce runoff and store floodwaters, including green infrastructure and more traditional methods, will be identified in a two-step process consisting of a **desktop evaluation** to screen for general site suitability and **field work** to refine identified opportunities.

Our approach is based on the U.S. Environmental Protection Agency's (EPA's) green infrastructure guidance documents,[1] EPA Region 1's current 2003 and draft 2014 General Permits for Stormwater Discharges from Small MS4s, Manchester-by-the-Sea's specific needs, and best professional judgment.

Flood Mitigation Practices for Consideration may include:

- Disconnection
- Rain harvesting
- Rain gardens (bioretention)
- Infiltration
- Street planters
- Porous/permeable pavement
- Flood plain conversion
- Above ground or subsurface flood detention ponds or swales
- Other more traditional flood structures

Quantifying Watershed Flood Controls

The overall process to include flood controls in a comprehensive watershed plan generally consists of the following major steps:

Step 1. A desktop (GIS-based) screening and ranking to identify and prioritize potential locations for flood;

Step 2. Comprehensive review of results of desktop screening and ranking, including site visits as needed to potential flood locations to further evaluate feasibility, collect information, and identify other site conditions that would impact implementation;

Step 3. Conceptual sizing of flood practices (volume treated, pollutant reduction, etc.);

Step 4. A hydrologic and hydraulic model evaluation to simulate how watershed responds to rain events with flood practice included;

Step 5. Calculation of pollutant load reduction for each BMP; and

Step 6. Development of costs for implementation and evaluation of cost vs. benefit.

It is critical to understand the amount and types of flood control that can be implemented, realistically and cost effectively, in a given watershed.

[1] http://water.epa.gov/infrastructure/greeninfrastructure/

Step 1: Desktop Screening (GIS Mapping Based Process)

Primary Screening: Bioretention and Infiltration Practice Favorability Criteria and Ranking

Favorability Ranking Score Criteria	High 5	Medium 3	Low 1	Figure #
Depth to Groundwater	>25 feet	>5 - 25 feet	0 - 5 feet	A1
Slope of Surface	0 - 5 %	5 - 10%	>10%	A2
Soil Permeability	Rapid (>20 in/hr)	Moderately rapid (6 to 20 in/hr)	Very slow to moderate (<6 in/hr)	A3
Transmissivity	High (>4,000 ft^2/day)	Medium (1,400 - 4,000 ft^2/day)	Low (<1,400 ft^2/day)	A4
Depth to Bedrock	>10 feet	5 to 10 feet	0 to 5 feet	A5

Primary Screening: Final & Parcel Ownership Criteria and Ranking (Map A6)

Favorability Ranking Score Criteria	High		Medium		Low
	1	2	3	4	5
Ownership	Municipal	Right of Way	Easement	Commercial / Industrial	Residential

Secondary Screening: Permitting and Environmental Considerations Criteria and Ranking

GIS Ranking Score Criteria	Favorable 1	Least Favorable 3	Figure #
Is the site within a FEMA flood zone?	No	Yes	A7
Is the site within close proximity to parcel with a septic system point (100 feet)?	No	Yes	A8
Is the site within a wellhead protection area?	No	Yes	A9
Is the site with NHESP Priority or Estimate Habitat?	No	Yes	A10
Is the site within close proximity to a certified or potential vernal pool (100 feet)?	No	Yes	A10
Is the site in protected open space?	No	Yes	A11
Is the site in a Massachusetts Historical Commission inventoried area or site?	No	Yes	A12

Criteria	Favorable GIS Ranking Score 1	Least Favorable 3	Figure #
Is the site near (approx. 100 feet) a contaminated site or an Underground Storage Tank?	No	Yes	A13
Is the site within Wetlands jurisdiction?	No	Yes	A14
Is the site within a future Flood Zone potentially expanded by sea level rise?	No	Yes	A15

Tertiary Screening: Qualitative Considerations

The Town may want to consider the following factors influencing implementation:

- What pollutants will the BMP remove (e.g. solids, nutrients, etc.)?
- How extensive is the level of coordination needed to implement the practice?
- What is the level of community support for the practice, both community-wide and in the neighborhood?
- Is the proposed location of the practice within a known flood-prone area? Does this area contribute to flooding problems downstream in the watershed?
- Will this installation of the practice enhance or preserve existing natural vegetation?
- Will the project cultivate educational opportunities?
- Will overhead or underground utilities need to be relocated for installation?
- How extensive are maintenance requirements and does the Town have the ability to complete maintenance?
- Will the project improve aesthetics for the area?
- Will the project improve wildlife habitat?
- Does this project overlap with another planned improvement to a building, parking area, or infrastructure on the site?

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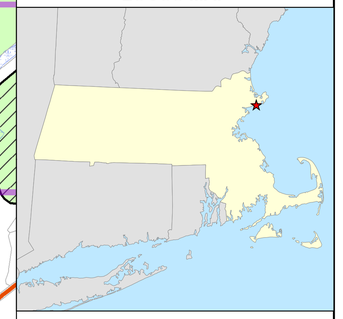
APPENDIX C

WATERSHED FLOOD MITIGATION OPPORTUNITIES

LEGEND

- Sawmill Brook Watershed
- Town Boundary
- Fire Station
- Police Station
- Wastewater Treatment Plant
- Schools (PK - High School)
- Town Owned Property
- Parcels
- MassDOT Culvert
- Culvert
- Inland Wetlands
- Coastal Wetlands
- Waterbodies
- Open Space

LOCUS MAP



0 250 500 1,000 Feet

1 " = 500 '

NOTES

Data sources: Town of Manchester-by-the-Sea, Office of Geographic and EnvironmentalInformation (MassGIS), Commonwealth of Massachusetts Executive Office of Environmental Affairs.

Sawmill Brook Culvert & Green Infrastructure Analysis
Manchester-by-the-Sea, MA

Tighe&Bond
June 2015

FIGURE 1

J:\M\M1476 Manchester MA Hydro Study\GIS\20150129SawmillBrookKickoffMap.mxd

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