USING GREEN INFRASTRUCTURE TO IMPROVE DROUGHT RESILIENCE IN THE COMMONWEALTH OF MASSACHUSETTS

Final Project Report

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ERG

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Table of Contents

I. Introduction

The purpose of this project was to explore how to integrate green infrastructure (GI), with a focus on drought resilience, into the Massachusetts State Hazard Mitigation Plan. The State Hazard Mitigation Plan is in the process of being updated and will be submitted to the Federal Emergency Management Agency (FEMA) in January 2018.

With droughts recently occurring in various parts of the country, including the Northeast, this project can serve as a model for how EPA Regional offices can collaborate with states and FEMA to optimize the use of GI to mitigate drought, as well as other hazards. This effort builds upon existing work in Massachusetts to promote low-impact development and GI practices to comply with state stormwater performance standards and National Pollutant Discharge Elimination System (NPDES) Phase II permit requirements, and it is intended to enhance an existing GI optimization tool and/or develop other approaches to identify areas where GI could be prioritized to accomplish multiple goals.

The project involved EPA Region 1's work with partners including FEMA, the Commonwealth of Massachusetts, and the Trust for Public Land (TPL) to provide the state of Massachusetts with options for ways to become more resilient to drought. This goal was accomplished through exploration of appropriate data layers and a process for integrating drought resilience in GI mapping, assessment of the state policy limitations and opportunities for drought resilience, and hosting a workshop on drought resilience. This report summarizes the results of these efforts.

Eastern Research Group, Inc., (ERG), and its subcontractor Horsley Witten Group, Inc. (HW), were tasked with presenting a methodology for identifying priority locations for implementation of GI measures to increase resilience to drought. This report presents a general methodology for site suitability that could be applied in varying settings across Massachusetts, using readily available data from the Massachusetts Office of Geographic Information (MassGIS) or local sources. This methodology could also be applied elsewhere in New England and beyond, but the availability of the data described here will most likely vary.

In developing the methodology, we drew upon prior experience developing iterations of this methodology in five communities of the Upper Charles River Watershed and in Dedham, Massachusetts; Stoughton, Massachusetts; Westwood, Massachusetts; and Medford, Massachusetts, among other areas, as well as many years of experience in watershed planning and in designing and constructing green stormwater infiltration practices. A draft of this methodology was presented to the project partners[1] on May 2, 2017. The methodology described in this report reflects the discussion at the May 2 meeting, additional discussion and feedback from EPA following that meeting, and Stakeholders Workshop held on June 26, 2017.

[1] The EPA Headquarters, TPL, FEMA, Massachusetts Department of Environmental Protection, Massachusetts Department of Conservation and Recreation, Metropolitan Area Planning Commission, Massachusetts Office of Energy and Environmental Affairs, and U.S. Department of Agriculture.

In addition to the methodology, we compiled a table of state policy limitations and opportunities as related to GI for drought. This information was gathered through interviews with staff from the Massachusetts Department of Environmental Protection (MassDEP), Department of Conservation and Recreation (MA DCR), the Executive Office of Energy and Environmental Affairs (EOEEA) and supplemental research. It was reviewed and commented on by project partners prior to presentation at the June 26th Workshop.

The half-day Stakeholders Workshop was held on June 26th, 2017, and involved presentations and discussions on the Massachusetts State Hazard Mitigation Plan update, general GI practices to address drought, the methodology for identifying locations for GI implementation, and the challenges and opportunities in implementing GI for drought.

Information from the June 26, 2017, workshop was synthesized to identify the following recommendations for incorporation into the State Hazard Mitigation Plan:

1. Identify priority areas for recharge in the state. Using the assessment method presented during the workshop - GIS Methodology to Identify Potentially Suitable GI Infiltration Sites (GIS Methodology)—and other available data and/or methodologies.
2. Identify and promote recharge for mitigation under the Water Management Act (WMA) by incorporating the GIS Methodology into state guidance for WMA permittees.
3. Align Municipal Separate Storm Sewer System (MS4) permit requirements with statewide stormwater standards, and review for consistency as well as potential opportunities for strengthening.
4. Promote implementation of GI for drought projects and provide technical assistance/ support to local communities, through the MS4 stormwater program's requirement that permittees identify five locations for stormwater infiltration practices.
5. Increase confidence in using GI practices through expanded training and education/outreach opportunities.
6. Promote GI practices statewide through incentives and/or through expanding jurisdiction of the stormwater standards.
7. Explore financial incentives for GI projects for drought including in-lieu fee (method for off-site compensatory mitigation by paying into a fund for systematic GI implementation within a watershed).
8. Partner with the Massachusetts Department of Transportation (MassDOT) and Federal Highway Administration (FHWA) to increase the opportunities to promote GI as well as the integration of potential projects into state and federal transportation planning. Explore opportunities with other state and federal agencies involved in planning and development.

II. Green Infrastructure to Enhance Drought Resilience

GI is an approach to manage the effects of urbanization, land development, and redevelopment. It is designed to mimic nature in reducing stormwater runoff and pollutants, and to increase groundwater recharge. "Green infrastructure" is a term that is used differently by different disciplines in different contexts. The term generally refers to practices that can be incorporated into the landscape that infiltrate, evaporate, or harvest and use stormwater runoff as close to its source as possible. The term can also include the preservation of open space or the reduction in impervious cover through better site planning to reduce the generation of runoff and maintain the natural capacity of the land to infiltrate rainfall. GI can be used at a wide range of landscape scales and in a range of settings, from urban to rural.

The GI approach is based on four fundamental principles:

- Treat stormwater as a *resource* rather than a waste product.
- Preserve, restore, or recreate natural landscape features.
- Minimize the effects of impervious cover.
- Implement stormwater control measures that rely on natural systems to manage runoff.

There are many different control measures and design variants that practitioners have developed to apply these principles, including bioretention facilities, rain gardens, vegetated rooftops, rain barrels/cisterns, infiltration practices, and permeable pavements, among others. By implementing GI design principles and practices, stormwater runoff is managed in a way that reduces the impact of built areas and promotes the natural movement of water through vegetation and soils. Applied on a broad scale, GI can help maintain or restore a watershed's hydrologic and ecological functions. GI has been characterized as a sustainable stormwater practice by the Water Environment Research Foundation and others.

GI practices designed to infiltrate runoff from developed areas or to preserve the natural infiltration capacity of a site can support drought resilience. According to the State Hazard Mitigation Plan (2013), "Drought is a period characterized by long durations of below normal precipitation. Drought occurs in virtually all climatic zones yet its characteristics vary significantly from one region to another, since it is relative to the normal precipitation in that region. Drought can affect agriculture, water supply, aquatic ecology, wildlife, and plant life."

Drought can be observed in severe reductions to stream flow, lakes, and ponds, as well as reduced water levels in groundwater wells and reservoirs that supply public and private drinking water. Drought can interrupt the availability of water for public consumption, irrigation, and natural habitats. Drought is a natural phenomenon, but its impacts are exacerbated by the volume and rate of water withdrawn from these natural systems over time as well the reduction in infiltration from precipitation that is available to recharge these systems. Natural infiltration is reduced by impervious cover (pavement, buildings) on the land surface and by the interruption of natural small-scale drainage patterns in the landscape caused by development and drainage infrastructure. Highly urbanized areas with traditional stormwater drainage systems tend to result in higher peak flood levels during rainfall events and rapid decline of groundwater levels during periods of low precipitation. Thus, the hydrology in these areas becomes more extreme during floods and droughts.

GI provides several benefits to help combat the cumulative impacts of drought. Precipitation and runoff that is infiltrated into the ground helps to recharge groundwater aquifers and support base flows in stream and rivers. The flow of water below the ground surface is slower and steadier over time than the event-driven flow of runoff via piped drainage systems. GI in the form of preserving undeveloped green space supports drought resilience by preserving the natural infiltration capacity of those open spaces.

In addition to drought resilience benefits, GI provides a multitude of other benefits, including:

- Improving water quality.
- Providing open space and connectivity.
- Reducing extreme heat in urban areas.
- Flood mitigation.
- Recharging groundwater for water supplies.
- Maintaining stream flow for fisheries.

A. Green Infrastructure Practices for Drought Resilience

There are a variety of GI practices that promote infiltration into groundwater and enhance resilience to drought. The following are some of the more common GI methods that can improve groundwater recharge and can help mitigate these impacts.

i. Bioretention Systems

Bioretention system in Lawrence, Massachusetts, installed during the redevelopment of a public school site.

Bioretention systems use soils and landscape vegetation to capture, store, treat, and typically infiltrate stormwater runoff. These systems include bioretention cells, stormwater planters, tree pits, and rain gardens. Bioretention systems rely on vegetation, in addition to filtration, to promote pollutant uptake, attenuation, and evaporation. These systems can be aesthetically appealing and help offset the urban heat island effect. A bioretention practice is typically designed for smaller drainage areas and storms. Bioretention practices include infiltrating systems on well-drained soils and filtering systems with an underdrain on poorly drained soils.

Bioretention systems can be situated to accept runoff from lawns, roads, roofs, or parking lots. These systems offer appealing design options for retrofit projects because they use existing green area, such as parking lot islands, to serve a functional purpose while adding aesthetic appeal. To create a bioretention system, existing green

Rain garden installed in a residential setting to capture driveway and roof runoff.

areas are excavated to provide storage, the soil is altered to promote uptake and infiltration, and suitable plants are selected for landscaping. These systems are not suitable for areas with minimal depth to bedrock, and they have significant limitations in very steep areas.

ii. Infiltration Practices

Infiltration practices capture and store stormwater to allow runoff to infiltrate into the sub-soil and ultimately recharge the groundwater. Infiltration practices include above-ground infiltration basins and trenches, and below-ground chambers and dry wells. Water is stored above the ground surface, in void spaces between gravel and stone, or in underground chambers. Above-ground practices use basins and trenches, while subsurface systems typically use chambers or dry wells. These systems generally do not offer the same aesthetic benefits as some other practices, as they are generally not landscaped with vegetation; however, they are generally less intrusive than detention ponds.

Infiltration practices can be sized to accept runoff from almost any sized drainage area. Pre-treatment using grass swales, filter strips, sediment forebays, or sediment basins is usually necessary so that the downstream infiltration system does not clog. Infiltration practices provide highly effective peak flow control and pollutant reduction, and they have the added benefit of groundwater recharge. These systems are not suitable for areas with poorly drained soils or high groundwater elevations, or sites with prior contamination.

Infiltration trench to recharge roof runoff.

iii. Permeable/Pervious/Porous Pavement

Permeable paving is used to capture and temporarily store rainfall from smaller storm events, dramatically reducing runoff volume compared to traditional paving. On sites with quickly draining soils, permeable pavement can be designed to infiltrate directly into the soil and recharge groundwater. Where infiltration is slow or not feasible, flow can be collected in an underdrain system and directed to other downstream practices. These systems consist of a porous surface, underlying layers of sand/stone, and an optional underdrain system for slowly draining soils.

Permeable paving surface made from recycled glass, installed in a new public park in Peabody, Massachusetts.

Permeable paving should generally be used in pedestrian-only areas and other low-volume, low-traffic applications like parking lots to capture precipitation before it becomes runoff and impacts any downstream facilities. However, some recent installations in high-traffic areas have proved successful where adequate maintenance by street sweeping with vacuum-assisted sweepers can be assured. Since permeable paving is installed over the land surface, it does not require any additional land consumption, so it would be an appropriate technique for many dense urban areas.

iv. Non-Structural Practices

Non-structural GI practices refer to design strategies that limit and reduce the impacts of development/redevelopment on the local environment. Urbanization typically increases pollutant/sediment loads and volumes of runoff leaving sites. Incorporating these non-structural practices into site design reduces runoff volume and enhances the quality of runoff, limiting the need for expensive structural systems to manage the effects of development. These practices include preserving open space, encouraging natural landscaping, retaining existing trees and vegetation on site, preserving topsoil, protecting wetland and stream buffers, and reducing impervious cover.

B. Additional Benefits of Green Infrastructure

GI practices also provide many co-benefits to humans and nature, in addition to the ability to infiltrate rainwater and runoff.

Water quality. GI practices described in this report also provide water quality benefits to receiving waters and groundwater. GI stormwater practices are very effective at reducing nutrients and sediments from stormwater, and they reduce pollutant loads simply by reducing runoff rates and volumes.

Cooling. GI practices can provide cooling within the urban built environment, as well as cooling for surface waters. An urban heat island results from pavement and rooftops that heat to temperatures far above local air temperatures and far above vegetated surfaces that are moist and shaded. These heated surfaces in turn create elevated atmospheric temperatures in urban areas. Many GI practices are vegetated practices, which help to counter the urban heat island effect by retaining moisture in their soils, enhancing cooling through evapotranspiration, and providing shade for the land surface. In addition, the water that is recharged is cooled to the temperature of the subsurface before it enters streams and rivers as base flow. These practices help to maintain the natural temperatures of streams and other surface waters, which sustains habitat conditions for aquatic organisms.

Connectivity. Vegetated GI practices and green spaces can create green (vegetated) and blue (hydrologic) connections across the landscape. These can be connections for humans, as well as habitat connections for animals and plants to move or transition across the landscape. In urban areas, GI can be incorporated into parks and open spaces as an attractive design element. Increased connectivity and access to green spaces also provide health benefits to residents in the neighborhood.

Flood mitigation. GI can reduce flood flows by slowing and infiltrating a portion of the runoff before it can contribute to the flood.

Water supplies. GI practices that enhance infiltration provide a direct benefit to water supplies, including both groundwater and surface water sources, by increasing aquifer recharge and storage. The recharge to the aquifer ultimately supports the groundwater available for well withdrawals and surface water withdrawals.

Stream flow for aquatic species. The recharge provided by GI practices described here also contributes to base flow in streams throughout the year, which enhances the availability and quality of stream flow habitat for aquatic species.

III. Characteristics of Suitable Sites for Infiltration

Although GI can be applied under various site conditions, locations where infiltration can be achieved provide significantly more drought resiliency than those where infiltration is restricted. Consequently, in places where the goal is to maximize drought resiliency, it is more cost effective to locate GI in areas where enhanced infiltration can occur. Sites in the built or natural landscape that are most suitable for enhanced infiltration using GI practices can be characterized by a set of basic conditions described fully in Table 1 and summarized below (highlight box).

In addition to the physical and regulatory characteristics described above, site suitability may be impacted by who owns the land and the potential costs of the GI practice that might be installed on the site. For example, land that is publicly owned (municipal, state, federal) might be less expensive for a municipality to use for GI than privately held land because it may have a lower or no effective land cost. Site suitability may also depend on whether the site is an open area, where surface GI practices might be implemented, or a densely developed area, where underground infiltration GI practices may be the only option. Underground practices are generally significantly more expensive to install than surface practices.

Site Suitability Criteria Summary

Data Type	Preferred Criteria
Wetlands	>50 feet away (>100 feet preferred)
Rivers	>100 feet away (>200 feet preferred)
Flood Zones	Outside of 100-year flood zone
Contaminated Sites	No contaminated sites
Soils	HSG A and B
Surficial Geology	Sand/gravel
Depth to Groundwater	> 4-foot separation
Depth to Bedrock	> 4-foot separation
SWMI Sub-Basin Rating	Groundwater Withdrawal Category > 3
Water Supply Protection	Outside Zone A or Zone 1

Table 1. Characteristics and Criteria for Sites Suitable for GI Infiltration Practices

Characteristic	GIS Data Layer and Source	Criteria
Site Conditions		
Permeable soils and sand/gravel surficial geology	Natural Resources Conservation Service SSURGO-Certified Soils (MassGIS) Surficial Geology 1:24,000 (MassGIS)	Soils that have a greater permeability, such as sand and gravel, have a higher capacity for infiltration and therefore require a smaller area to infiltrate a given volume of water than tighter soils, such as till. Sites located on Hydrologic Soil Group (HSG) A soils are considered more suitable than sites located on HSG D soils. In some urban areas where the mapped soil type is identified as "Urban Land," it is not possible to know the infiltration capacity of the soil without additional soil evaluations. In these cases, additional information can be gleaned from the surficial geology mapping. Areas that are underlain by sand and gravel surficial geology are likely to have a suitable infiltration capacity below the urban land soil.
Depth to groundwater and bedrock	Natural Resources Conservation Service SSURGO-Certified Soils (MassGIS)	Areas where depth to groundwater and depth to bedrock are greater are better suited for GI stormwater management practices than areas with a shallow depth to bedrock and groundwater. A depth to groundwater or bedrock of at least 4 feet is consistent with the Massachusetts Stormwater Management Standards.
Shallow slope	Light Detection and Ranging (LiDAR) (MassGIS)	Sites that have a shallower slope (for example, 15-percent slope or less) are better able to capture onsite rainfall and slow stormwater runoff to provide more opportunities for infiltration to occur.
Flow accumulation	Must be created from LiDAR (MassGIS) using ArcGIS Spatial Analyst Flow Accumulation Tool. Weighted Flow Accumulation Grid uses Impervious Surface data layer (MassGIS).	In order for a site to collect runoff for infiltration, the site must be located within the flow path of runoff from upgradient areas. If water cannot flow to a site, the site can only infiltrate the water that falls directly on it. Therefore, GIS tools such as ArcGIS Spatial Analyst can be used to estimate the flow accumulation for the drainage area converging at any location within the study area. The output of this analysis is a Flow Accumulation Grid layer. This estimate will be more accurate and relevant in an area where the drainage hydrology is not heavily altered by piped drainage infrastructure, as in rural or suburban settings. In urban settings, piped drainage can distort the natural flow accumulation at a given location. In addition, this grid can be weighted by the percent impervious area within the flow accumulation area (contributing drainage area).
Regulated Areas Where Implementation Is Restricted		
Wetlands, rivers, and associated buffers	MassDEP Hydrography 1:25,000 Buffers must be created. For example: • 50 foot and 50–100 feet of wetlands • 100 feet and 100–200 feet to perennial streams and rivers	Wetlands, streams, rivers, and their associated buffers are protected by state and local wetland protection regulations. State regulation (310 CMR 10) governs activities within 100 feet of wetlands and within 200 feet of rivers, and while the installation of GI infiltration practices would not be prohibited, these practices are more difficult to design and permit. Local regulation can be more restrictive than state regulation in protecting these areas. In addition, natural conditions within this proximity of wetland resources are less likely to be suitable for GI installations. However, preservation of natural lands, considered as a different GI approach, is highly prioritized within these buffers for water quality protection, flood mitigation, and habitat protection purposes. Infiltration in areas beyond these buffers provides for a longer flow path prior to emergence in streams, lakes, and rivers, and consequently better drought resiliency.
Water Supply Protection Areas	Wellhead Protection Areas (MassGIS) Source Water Supply Protection Areas (MassGIS)	The contributing area directly surrounding a public surface water supply or groundwater supply well is protected by state and local water supply protection regulations. These areas are designated at Zone A (within 400 feet of source surface water and within 200 feet of tributary/associated surface waters) for surface water supplies and Zone 1 (400-foot radius) for public groundwater supply wells. Stormwater infiltration practices within these areas are prohibited in order to reduce the potential for introducing pollutants into the water supply. However, preservation of natural lands, considered as a different GI approach, is highly prioritized within these contributing areas for water quality protection purposes.
Flood hazard zones	FEMA National Flood Hazard Layer (MassGIS)	GI infiltration practices should generally be constructed in areas that are outside of mapped flood hazard zones (located within Flood Zones D or X) to avoid damage to the practice. In addition, wet, poorly drained soils and shallower groundwater depths within these flood zones are likely to render the site unsuitable for GI infiltration practices. However, preservation of natural lands, considered as a different GI approach, is highly prioritized within these contributing areas for flood mitigation and habitat protection purposes.

Characteristic	GIS Data Layer and Source	Criteria
Contaminated sites (Activity and Use Limitations [AULs] and 21E sites)	MassDEP Oil and/or Hazardous Material Sites with Activity and Use Limitations (MassGIS) MassDEP Tier Classified Chapter 21E Sites (MassGIS) Buffers can be created to account for inaccuracies in the data. For example: • 200- or 500-foot exclusionary buffer to AUL and 21E locations.	Infiltration should be avoided at sites with contaminated soils because contaminants can be mobilized by the increased movement of water through the soils. Contaminated or potentially contaminated soils can be determined at a landscape scale by identifying “Chapter 21E” sites, which are sites where a spill or disposal of oil or hazardous materials has been reported to the state under state law (MGL Chapter 21E) and sites with AULs in accordance with the Massachusetts Contingency Plan. Because the location of the AUL or 21E site does not always accurately represent the site of contamination, creating an exclusionary buffer around the parcel helps to avoid potentially contaminated areas.
Additional Data and Characteristics		
Flow-stressed basins	MassDEP Groundwater Withdrawal Category layer (MassDEP)	The process of prioritization of areas for infiltration to enhance drought resilience should also consider areas within flow-stressed basins. Areas that experience flow stress even under non-drought conditions, as a result of water withdrawals or flow modifications, can benefit from GI practices that enhance infiltration. These basins can be identified using the Massachusetts Sustainable Water Management Initiative (SWMI) Groundwater Withdrawal Category (1 through 5) data.
Parcel boundaries	MassGIS or municipality	Parcels form the basis for the site suitability analysis, and all data is ultimately analyzed on a parcel-by-parcel basis.
Parcel ownership	MassGIS or municipality	Parcels owned by public entities may be easier or less costly than private parcels to retrofit with GI infiltration practices or to conserve as open space, if it is the municipality that is undertaking the retrofit. Therefore, the analysis may exclude privately owned parcels or rank them differently.
Land use	MassGIS or best available	Land use in combination with soils and geology is used in future steps to derive estimate runoff generation, and it is helpful in identifying existing open spaces that may be available for GI infiltration practices or for open space preservation.
Existing drainage and stormwater best management practice (BMP) locations	Municipality	Mapping of the existing drainage infrastructure and locations of existing stormwater BMPs can help inform the site suitability analysis. Areas where existing drainage can be diverted to a suitable recharge site are more feasible for construction. Existing stormwater practices such as large detention basins can sometimes be easy candidates to be retrofitted as a GI infiltration practice.

IV. GIS Methodology to Identify Potentially Suitable Green Infrastructure Infiltration Sites

A desktop GIS analysis can be performed using a combination of criteria to identify potential sites for the implementation of GI practices to enhance or protect infiltration in the landscape. The various criteria are rated and scored and then combined to develop a site suitability map. The methodology can be adjusted depending on the needs of the analysis. The GIS analysis methodology is provided below, along with two examples of how to adjust the methodology for different settings or different types of target areas.

A. Basic Methodology

The purpose of this analysis is to identify sites with the potential for recharge that could be easily retrofitted or designed with a new GI practice to capture and recharge stormwater runoff. This methodology is useful for identifying sites that would be able to capture and recharge runoff from a relatively large (> 1 acre) contributing area with impervious area that generates runoff. These are referred to as "offsite GI practices."

Step 1. Rating System

To perform this analysis, the first step is to design a rating system for the important criteria that reflects the study area and the needs of the user performing the analysis. As a start, we suggest the rating system presented in Table 2. This rating methodology reflects conditions and typical regulatory constraints in Massachusetts, and it could be adjusted for different regulatory constraints at the local level or in other states. Each criterion described in the columns of Table 2 is assigned a rating score between 0 and 5, with 5 being the highest score for that factor.

Step 2. Scoring Analysis

The scoring analysis is performed by combining the rating scores for each criterion. This can be done in a variety of ways, including adding scores and multiplying some scores. Scores can be multiplied either to enhance the weighting of a certain criterion (for example, soil HSG) or to exclude certain sites entirely (such as contaminated sites, which have a rating of 0). In addition, it can be helpful, and is likely necessary, to run the analysis multiple times so that the user can make adjustments in the weighting factors to help home in on certain priorities.

For example, we performed a desktop GIS-based suitability assessment for the Town of Milford, Massachusetts, using the rating system described in Table 2 and the suitability calculation presented below.

Rule for Outright Exclusions of Certain Sites:

First, we exclude certain sites from consideration if any of the following criteria has a rating of zero:

- Depth to Groundwater
- Depth to Bedrock
- Regulated Waterbody

- AUL/21 E Site
- Water Supply Protection Area

In other words, we exclude from consideration any site that has a depth to groundwater or bedrock of less than 2 feet, is located within 50 feet of a wetland or within 100 feet of a river, is on a parcel within an AUL/21E site, or is located within a Zone A or Zone 1 Water Supply Protection Area.

Site Suitability Score:

$$(\text{Soils x 2}) + \text{Depth to Groundwater} + \text{Depth to Bedrock} + \text{Surficial Geology} + (\text{Regulated Waterbody x 2}) + \text{FEMA Flood Zone} + \text{AUL or 21E} + \text{SWMI Basin} + \text{Water Supply Protection Area} = \text{Site Suitability Rating}$$

Max Value = 55

Implementation Suitability Score:

$$\text{Slope} + \text{Onsite Impervious Cover} + \text{Contributing Impervious Area} + \text{Preliminary Loading Ratio} + \text{Existing BMP} = \text{Site Implementation Suitability}$$

Max Value = 25

Total Suitability Score:

$$\text{Site Suitability} + \text{Implementation Suitability} = \text{Total Suitability Score}$$

Max Value = 80

Further Evaluation of Priority Sites:

Once the sites are prioritized, the user can further differentiate between publicly and privately owned sites, if that is of importance to the user.

In this example, the Regulated Waterbody Rating reflects whether or not the site is located outside of the buffer to a wetland or river, and the Water Supply Protection Zone Rating reflects whether or not the site is located outside of the Zone A or Zone 1 of a public water supply. The final score was determined by adding the Site Suitability Score and the Implementation Suitability Score. Figures 1 through 3 present the results from this analysis for Milford, Massachusetts. Figure 1 presents the Site Suitability results, Figure 2 presents the Implementation Suitability results, and Figure 3 presents the Total Suitability results. On each map, the darker areas represent the areas that are more suitable for GI infiltration practices and the lighter areas are those that are less suitable. Some areas that appear to be more suitable in Figure 1 may appear to be less suitable for implementation in Figure 2 (or vice versa). However, when the suitability ratings are combined in Figure 3, those same areas may remain among the most suitable simply because the Implementation Suitability ratings presented in Figure 2 hold less weight in the overall suitability calculation. The maximum value for Site Suitability is 55, which is more than twice as much as the maximum value for Implementation Suitability. These weighting and ranking decisions can be adjusted at the discretion of the user performing the assessment, to best reflect the priorities of the assessment.

In performing this example site suitability assessment, we encountered a few data constraints that required adjustment. For example, within the study area of the Town of Milford, there was no available data for the depth to bedrock. All map units had a null factor (‘0’). As a result, depth to bedrock was not included as an assessment criterion. In addition, we found that almost half of the map units had no data or a null factor of 0 for depth to groundwater. Therefore, these locations were excluded from suitability. These types of data constraints are real—and common—and they must be evaluated each time a suitability assessment is performed. In cases where the results appear to be markedly narrow or skewed due to known data limitations, the rating system and scoring equations can be adjusted to meet the needs of the user.

Alternatively, instead of using a rating system to score each criterion, the site suitability analysis could be simplified to use a binary query format in which a site either meets or fails to meet a set of priority criteria. Using this method, each parcel or grid square in the study area would be evaluated against a set of criteria, and only those that meet all criteria would be selected. This is essentially the approach that could be employed using a tool such as the TPL’s Climate-Smart Cities tools for the Metro Mayors Region or the City of Boston. The Climate-Smart Cities tool is discussed in Section IV.F.

Table 2. Rating Chart for Criteria Used to Identify Potential GI Sites for Recharge

Rating[1]	Criteria													
	Site Suitability								Implementation Suitability					
	Soils	Depth to Groundwater/ Bedrock	Surficial Geology	Regulated Waterbody	FEMA Flood Zone	AUL/21E Sites	SWMI Sub-Basin Rating	Water Supply Protection Zone	Ownership	Slope	Onsite Impervious Area %	Contributing Impervious Area	Preliminary Loading Ratio	Existing BMP Rating
0		0 feet	No data	Within 50 feet of wetlands or 100 feet of rivers		On a parcel within an AUL/21E site		Inside Zone A or Zone 1	Private	> 15%	> 75%	< 0.1 acres	> 20:1 or < 1:1	No existing basin or no data
1	HSG D	2 feet	Till or bedrock		Zones A, AE, AH, AO, and VE		1			12% to 15%	50% to 75%	0.1 to 1.0 acres	1:1 to 3:1	
2	HSG C	4 feet	End moraines or fine-grained deposits				2			8% to 12%	25% to 50%	1 to 5 acres	3:1 to 5:1	
3		6 feet	Sandy till over sand of floodplain alluvium	Within 50–100 feet of wetlands or 100–200 feet of rivers		Within 500 feet of a parcel with an AUL/21E site	3		Public (not including town/city-owned)	4% to 8%	10% to 25%	5 to 10 acres	5:1 to 10:1	Existing stormwater basin (inside wetland/river buffer)
4	HSG B	8 feet	Large sand deposits				4			2% to 4%	5% to 10%	10 to 15 acres	10:1 to 15:1	
5	HSG A	≥ 10 feet	Sand and gravel deposits	Outside 100 feet of wetlands or 200 feet of rivers	All other zones	More than 500 feet from a parcel with an AUL/21E site	5	Outside Zone A or Zone 1	Town/city-owned	0% to 2%	< 5%	> 15 acres	15:1 to 20:1	Existing stormwater basin (outside wetland/river buffer)

[1] The ratings apply to each criterion individually and do not represent a set of criteria that together characterize a given site. For example, a given site can have a rating of 2 for one criterion and a rating of 5 for another criterion.

Figure 1. Milford, Massachusetts, Infiltration Site Suitability Results

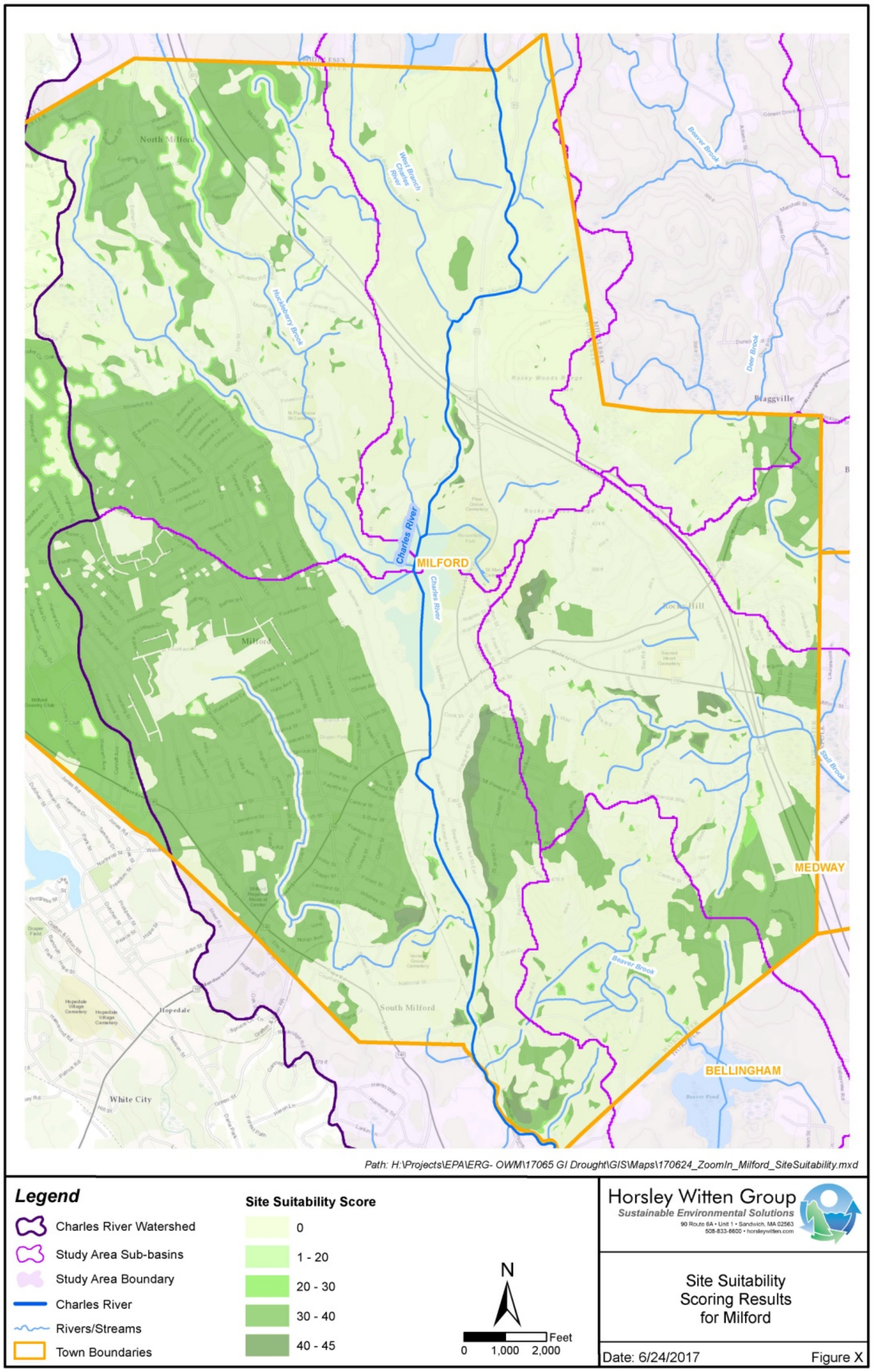


Figure 2. Milford, Massachusetts, Infiltration Implementation Suitability Results

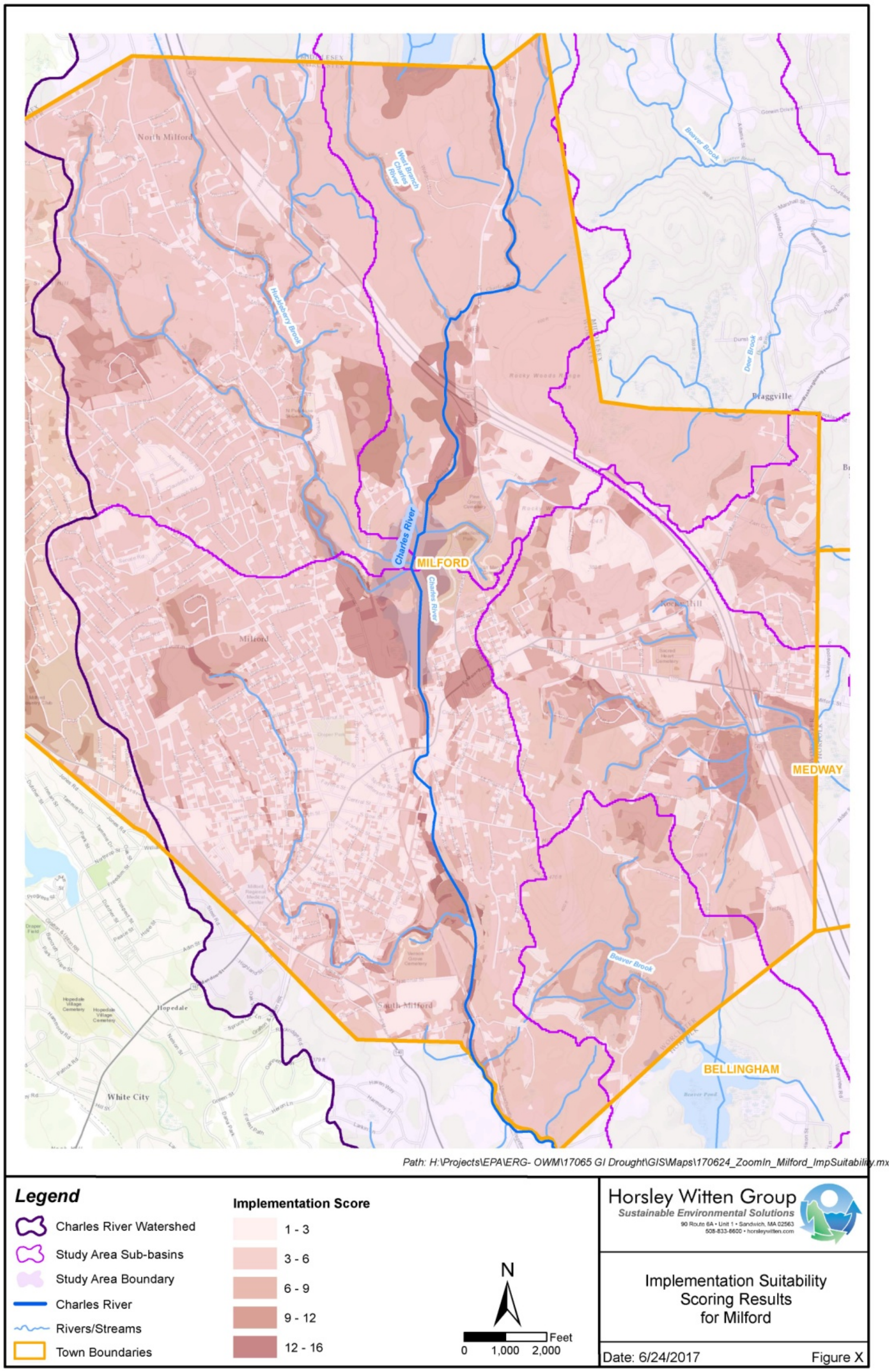
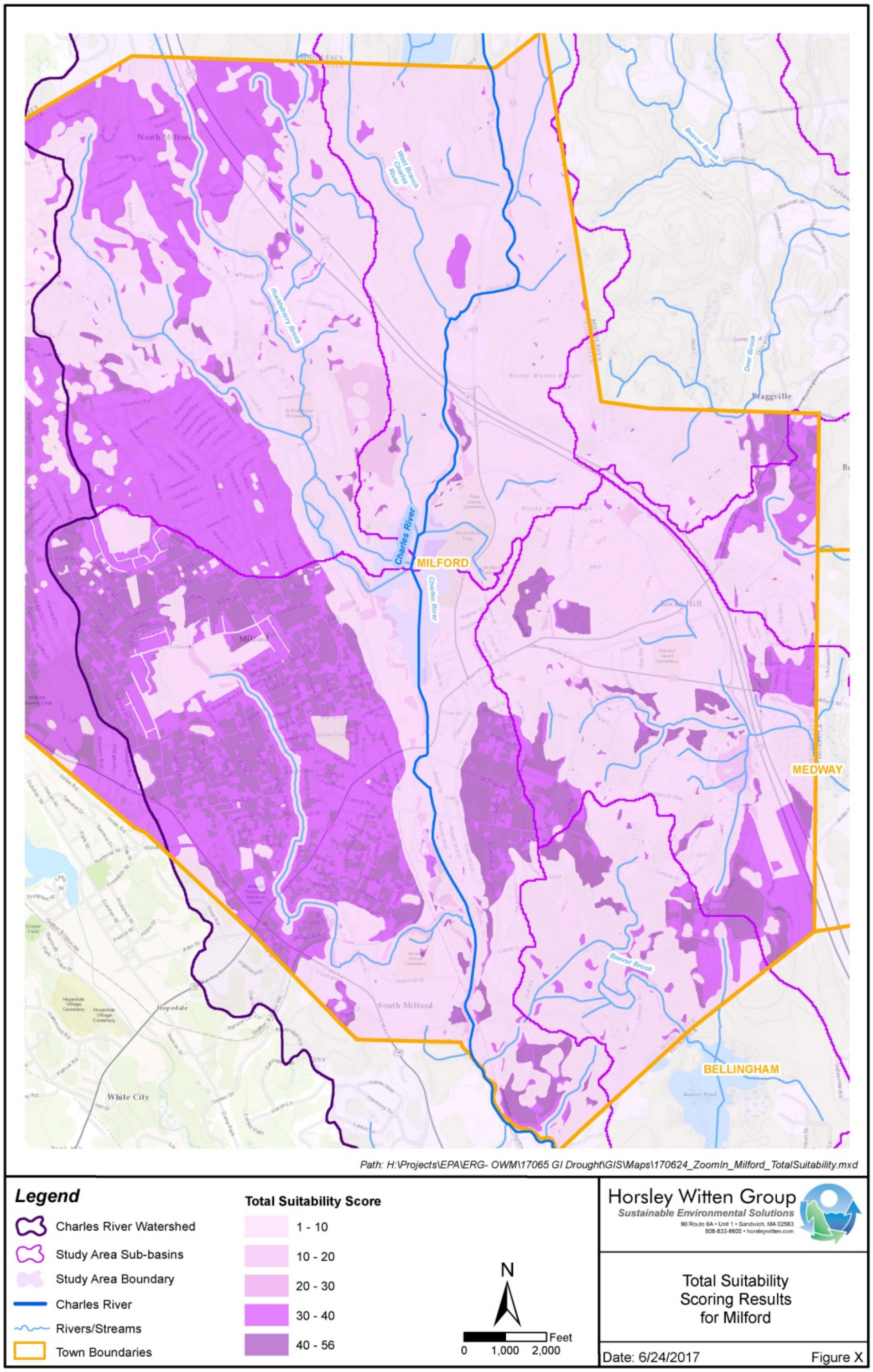


Figure 3. Milford, Massachusetts, Total Suitability Results



B. Alternative Option 1. Evaluate Sites for Suitability for Small, Onsite Infiltration Practices Within Existing Developed Area

The purpose of this analysis option is to evaluate the suitability of small sites for recharge from small areas of impervious cover. These areas could be retrofitted with small-scale GI practices with the goal of creating a network of small practices throughout the landscape. These are referred to as "onsite GI practices." This option is essentially the reverse of the methodology presented above, in that the user starts with a known site or set of sites of interest, and then uses the available data and the ranking system to evaluate and compare the sites. For example, if a homeowner or neighborhood of homeowners was interested in installing small GI practices, such as rain gardens, in their neighborhood, the homeowners could use the same steps described in the methodology above but focus only on the known target area. This could help the homeowners to evaluate where to consider implementing the rain gardens and perhaps where to avoid implementation.

C. Alternative Option 2. Identify Existing Undeveloped Areas for Conservation

The purpose of this analysis option is to identify undeveloped areas that provide natural infiltration in the landscape in their undeveloped condition and do not generate more runoff than natural conditions, so that such lands can be protected as natural landscape-scale GI. These areas could be forested areas, open fields designated as having prime agricultural soils, or other undeveloped open spaces. The goal in performing this analysis is to avoid developing areas that provide the greatest benefit for nearby streams and rivers, and to protect them for their natural infiltration capacity or enhance them with additional GI stormwater practices.

This analysis is a much simpler use of the ranking methodology. The goal is to identify areas that represent the intersection between open lands and permeable soils/geologic conditions so that these lands can be targeted for long-term open space preservation. If the entity doing the analysis is interested in prioritizing publicly owned property, that element could be included in the query as well, so that privately held lands would be excluded. Furthermore, it may be useful to exclude areas that are already protected in perpetuity. This data can be obtained through the MassGIS Protected and Recreational Open Space data layer.

For the basic analysis, we recommend a simple binary query analysis, in which areas that meet all criteria (open space, soil permeability, ownership, and/or level of protection) are identified. Additional data layers, such as slope, location relative to Water Supply Protection Areas, or location relative to wetland buffer zones, could be useful to further characterize and analyze the identified parcels. These other characteristics would be useful in identifying other benefits provided by the sites, and they may help prioritize the sites according to the needs and perhaps budget of the state, municipality, or other entity performing the analysis.

D. Applying Site Suitability Methodologies for Different Settings

The site suitability methodology will produce different results in different development settings, depending on how the ranking is structured and applied. Options 1 and 2 above illustrate this difference. The ranking approach is flexible and can be adjusted for different targets and types of settings. A discussion of which approach may be best suited to which setting is provided below.

i. Urban Setting

In an urban setting, where development is more dense, impervious cover comprises more of the landscape, and opportunities for GI installations may be on a smaller scale. Therefore, Alternative Option 1 may be the most helpful to identify GI opportunities, though the use of other methods may be beneficial if larger treatment areas are available (e.g., identifying regional practices near stormwater outfalls).

ii. Suburban and Rural Settings

Sites suitable for larger-scale GI infiltration practices are more readily available in suburban and rural settings, where more land is available, development is less dense, and buffers of green space still exist adjacent to large impervious areas such as roadways, parking lots, schools, and other large-scale institutional sites. For this reason, the basic ranking methodology may be the most useful in these settings. However, Alternative Option 2 can also help to evaluate small-scale sites in suburban areas. Suburban and rural settings are also ripe for small-scale sites suitable for small GI, such as rain gardens, to treat residential rooftops and driveways.

iii. Rural Setting

Alternative Option 2, for the purpose of identifying areas suitable for conservation, is likely to be of more use in rural settings than suburban settings, although it can yield potentially informative results in all three settings.

iv. Adapting the Approach with a Focus on Widespread Implementation of Green Infrastructure

As discussed above, the default methodology to identify GI sites emphasizes prioritizing locations for GI practices in areas with higher-permeability soils and geologic materials. This logic recognizes that the most cost-effective locations to recharge groundwater are those where it is easier to infiltrate larger volumes of water. This will make sense in many situations where users of the methodology are faced with budget limitations, constrained sites, and the need to prioritize implementation projects.

However, it is important to recognize that the areas of recharge cannot necessarily be restricted to only the places with the best infiltration potential. Recent research at the University of Massachusetts–Dartmouth Department of Geosciences (Boutt, D., 2016) reports that more than 60 percent of New England’s land area is comprised of upland, thin glacial till geology with less-than-ideal infiltration characteristics. This large area of glacial till feeds many headwater streams, ponds, and lakes across the region. It also means that it is vitally important to maintain or even enhance recharge in these hard-to-infiltrate till areas. So for areas that have significant till area and sensitive receptors, users of the methodology can modify the default ratings in Table 2 by giving a higher rating for the soils and surficial geology categories that represent till soils and geology. This will likely result in more sites being identified as potential candidates for GI implementation. Users will still need to take additional actions to move towards implementation, as described in the following section.

As our understanding of the opportunities and benefits of GI grows, we have learned that not every site needs to infiltrate a somewhat-arbitrary large volume of, say, "one inch of runoff." Sites can contribute significantly to recharge and pollutant load reduction by infiltrating volumes as small as 1/3 or 1/4 inch. While a lower infiltration rate will result in a larger footprint and typically a higher cost, it does not mean that these sites are neither feasible nor valuable. In fact, some argue with justification that widespread implementation of smaller facilities (infiltrating smaller volumes) across the landscape is potentially more beneficial than a smaller number of facilities infiltrating larger volumes.

E. Going from Potential Site Suitability to Implementation

The desktop GIS analysis to identify potentially suitable sites for GI infiltration practices is an important first step in analyzing an area. This step is generally followed by:

- *Refining the site suitability results.* The site suitability results should always be reviewed for quality control to ensure that the data are accurate, that the rating system is producing results that are helpful (not too many or too few sites), and that sites that should appear on the list have not been missed. It is always good practice to check the results visually against individual data layers and your own knowledge of an area to check that the rating formula that is being used is producing the results that you would expect. If certain "good" sites that you know about are being missed, it is time to review the methodology, data accuracy, and rating system. This review can result in adjustments to the rating system, adjustments in the criteria selection, and/or a simple adjustment to the results by adding or removing certain sites based on a working knowledge of the sites.

- *Performing an implementation suitability analysis.* Sites that are identified as suitable for recharge may not be suitable for implementation due to site-specific limitations, such as conflicts with existing utilities on site or adjacent to the site. Implementation may also be difficult if the actual layout of the property is unsuitable for a GI retrofit or if the open space on site is dispersed and not large enough for a GI practice. An implementation suitability analysis that relies on GIS-based data is only feasible if there are additional data available in GIS that would facilitate this analysis, such as utility data. In some cases, this step may have to be addressed in the site visit stage.

- *Visiting sites.* Once a set of sites is identified as priority areas for further investigation, site visits are extremely valuable (some would say mandatory) in taking the assessment to the next level of detail. In many cases, a site visit will rule out a site because the site may just be different than what you expected, conditions may have changed since the date of the GIS data, or the GIS data may not be completely accurate. Site visits can also help to identify utility conflicts, construction projects underway, or other potential conflicts with GI practices. Site visits are also the first real opportunity to identify potential GI practices for a given site, and whether the available area is truly adequate to manage the contributing area. This stage is really when the list of potentially suitable sites gets whittled down to candidate locations.

Special Note for Urban Settings: In urban settings in particular, the desktop GIS site suitability assessment will require a more significant quality-control effort, as well as a more significant follow-on effort to evaluate additional information and constraints about each site, including site visits. In urban settings, these types of additional issues arise much more frequently than in suburban or rural settings. Additionally, the biggest limiting factors are probably the actual subsurface conditions related to soils, groundwater depth, and potential prior contamination. Typical GIS mapping data for these parameters are planning-level at best, and they are frequently different at the site scale; this is most true in the ultra-urban setting.

F. A Tool for Green Infrastructure Site Suitability: Trust for Public Land's Climate-Smart Cities™ Tool

TPL has been developing a web-based GI site suitability tool for various communities around the country. In Massachusetts, they have developed the Climate-Smart Cities Tool for the City of Boston,[1] and they are just now finalizing a similar web-based tool for the Boston Metro Mayors Region, a group of 14 cities in the Boston metro area supported by the Metropolitan Area Planning Council (MAPC). This tool includes several embedded analyses to identify priority areas for GI based on a variety of criteria and GI benefits. In addition, the tool allows the user to view data layers and run live queries using the available data layers to produce summary maps and output tables that identify priority sites. Data for the tool has been compiled from a variety of sources, including MassGIS, as well as individual municipalities. Many of the data relevant to the recharge site suitability methods were already included in the TPL tool prior to the start of this project to examine the use of GI for drought resilience. During this project, TPL worked with the HW/ERG team to incorporate additional data layers into the tool under a separate menu targeting drought resilience, so that the user could query a study area for potentially suitable sites for GI infiltration practices. Table 3 presents a summary of additional data layers that TPL has added to the tool to implement a query similar to the assessment method described in this report.

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[1] http://web.tplgis.org/Storymaps/CSC_Boston/cascade/index.html

Table 3. Data Layers Added to the TPL Boston Metro Mayors Climate-Smart Cities Tool

Data Layer	Data Source	Already in TPL Tool	Added to TPL Tool
SSURGO Soils (Hydrologic Soil Group)	MassGIS	✓	Categorized by HSG
Surficial Geology	MassGIS	X	✓
Wetlands	MassGIS	✓ with 200-foot buffer	Created 50-foot buffer
River Centerlines	MassGIS	✓	Created 100-foot buffer
Parcels (including identifying public property)	MassGIS	✓	✓
Depth to High Groundwater	MassGIS	X	✓
Depth to Bedrock	MassGIS	X	✓
Water Supply Protection Areas (Zone 1 Wellhead Protection Areas and Zone A Surface Water Protection Areas)	MassGIS	X	✓ *Note: There are no Zone 1 Wellhead Protection Areas in the study area.*
Flow Accumulation Grid	Derived from LiDAR using ArcGIS Spatial Analyst tool	X	Potentially to be added in the future.
Contaminated Sites	MassGIS	✓	Created 500-foot buffer

Ideally, an analysis using the methodology or methodologies described in this report could be embedded in the Climate-Smart Cities Tool so that the user does not need to create a separate and unique query for each analysis. The TPL Climate Smart Cities Tool framework includes four primary analyses to identify sites where GI could be used to meet four objectives:

- *Absorb*, which addresses stormwater management;

- *Connect*, which addresses carbon-free transportation links;
- *Cool*, which addresses urban 'heat island' effect; and
- *Protect*, which addresses the protection of shoreline buffers and parks for flood protection.

The tool contains an embedded spatial analysis to address each of the four objectives and identify sites to meet those objectives. The GI suitability analysis presented in this report could be accessed similarly to the existing *Absorb*, *Connect*, *Cool,* and *Protect* analyses. The user can adjust the weighting allocated to certain elements of the query based on their needs. But the majority of the geoprocessing for the analysis would be done upfront to create summary data layers. An important example of the data that could be produced ahead of time would be the flow accumulation grid. However, we understand that the effort to embed this analysis within the tool requires a significant effort.

In the absence of the embedded tool, the Climate-Smart Cities Tool can be employed to perform a simple site suitability query. The tool's query function allows the user to create a set of conditions across multiple data layers, and the tool generates a map and table of sites that meet the query criteria. This query is performed on a parcel basis, as all data available for the query function are tagged to the parcels. The tool also can be useful for the implementation of Alternative Option 1, where the user has a site in mind and is looking to evaluate the conditions at the site, because the user can simply view different layers at the site of interest and make note of the site characteristics as they pertain to GI suitability for recharge.

The Climate-Smart Cities Tool also provides an easy mechanism to evaluate the additional climate resilience benefits to society generated by additional GI in the locations identified using the suitability method. Users can readily evaluate how these sites relate to areas targeted as most in need of improved bike-walk connections, in need of cooling to combat significant urban heat island effects, or in need of increased protection from anticipated coastal and inland flooding. An evaluation of the co-benefits of potential GI projects can help to prioritize the projects and generate support for their implementation.

G. Site Suitability Methodology Conclusion

The methodology described in this report is a planning-level assessment of potential GI recharge locations. This methodology is best implemented at a local scale, across a municipality, a small watershed, or a village/neighborhood. It can be adjusted to meet the specific needs of the user, the availability and accuracy of data, and the GI targets (large-scale, small-scale, or conservation). We have intentionally tried to present a methodology that can be implemented with readily available data (in Massachusetts, data are mostly from MassGIS). However, users can certainly enhance this methodology with additional data that may be more accurate or up to date than the MassGIS data.

All results from this methodology must be reviewed to ensure the results are logical, reasonable, and useful (not too many or too few sites). Users can expect to make several rounds of adjustments to the criteria and ratings along the way, before developing an output map that meets their needs.

Ultimately, this methodology is a tool to assist communities in planning for GI implementation, preserving suitable sites and incorporating GI practices at suitable sites as opportunities arise. Implementation of GI practices at suitable sites can increase base flow and support resilience of water supplies and aquatic habitats in the face of drought.

V. Limitations to and Opportunities for Green Infrastructure Implementation

In addition to developing the methodology to identify suitable sites for GI infiltration projects, we conducted interviews with MassDEP, Massachusetts EOEEA, and MA DCR staff to develop a preliminary analysis summarizing the limitations as well as the opportunities for GI implementation in Massachusetts. The full results are presented in Appendix A and include preliminary analysis of:

- Water Management Act, MGL Ch. 21G; 310 CMR 36.00 (MassDEP)
- MS4 permits (314 CMR 9.00 and 10.00) and U.S. EPA NPDES program
- Underground Injection Control (Safe Drinking Water Act), 310 CMR 27.00 (MassDEP); Title 40 CFR (EPA)
- Massachusetts Wetlands Protection Act, MGL Ch. 131 S.40; 310 CMR 10.00 (MassDEP and local conservation commissions)
- Massachusetts River Protection Act, 310 CMR 10.5
- Drinking Water (Wellhead Protection Regulations), 310 CMR 22.00: Drinking Water Regulations 310 CMR 22.02, 22.03, and 22.21 (MassDEP)
- Interbasin Transfer Act and Regulations, MGL Ch. 21 S. 8 B-D; 313 CMR 4.00 (MA DCR and Massachusetts Water Resources Commission)
- Water Quality Certification Regulations (2008), 314 CMR 9.00 (MassDEP)
- Local ordinances/bylaws

There were also several non-regulatory limitations and opportunities examined (Appendix B), including:

- Transportation and other development projects
- Massachusetts State Building Code 780 CMR 10.00
- Professional community of practice
- Maintenance
- Redevelopment
- Massachusetts Drought Management Plan
- Community Preservation Act (MGL Ch. 44B)
- Massachusetts Green Communities Program
- Integrated water resources planning
- Community participation in the FEMA Community Rating System for Floodplain Management
- State grants

VI. Workshop Discussion and Recommendations

The results of the preliminary scan of the limitations and opportunities in Massachusetts for GI for drought helped shape the agenda for the June 26th, 2017, Stakeholders Workshop. The workshop had three main objectives:

- Present the results of the GI optimization mapping exercise (see Section IV).
- Provide feedback on the state policies and regulations limitations and opportunities analysis (see Appendices A and B).
- Discuss best strategies (e.g., address regulatory barriers, disseminate GI assessment methodology across the state) to improve drought resilience in the Commonwealth.

Approximately 40 representatives of federal, state, and local governments and non-profit organizations attended the workshop and discussed the mapping method and the potential limitations, challenges, and opportunities in Massachusetts' laws, policies, and programs to advance GI practices for drought resilience.

Participants broke into small groups to further discuss limitations, challenges, and options for overcoming those barriers of interest to them. They were presented with a summary table of potential opportunities derived from the limitations/opportunities summary matrix and invited to discuss each in greater detail:

Table 4. Synthesis of Potential Opportunities to Advance and Accelerate the Adoption of GI for Infiltration

Potential Opportunities	Questions to Consider	Workshop Discussion Recommendations (report recommendations in bold)
1. **STATEWIDE JURISDICTION**—Many activities are outside regulatory jurisdiction and represent lost opportunities for recharge; how can we think systematically about where the most productive and successful efforts might be to broaden application of infiltration standards for: a. New development (both inside and outside MS4 areas). b. Redevelopment (both inside and outside MS4 areas).	• What are the most significant opportunities for recharge that are lost because they fall outside regulatory jurisdiction? • How can the state incentivize infiltration statewide (outside jurisdictional areas)? • What might the most effective and strategic approaches be for increasing jurisdiction?	• **Promote GI practices statewide through incentives and/or through expanding the jurisdictional area of the stormwater standards.**

Potential Opportunities	Questions to Consider	Workshop Discussion Recommendations (report recommendations in bold)

2. **TRANSPORTATION—**Where there are transportation projects being undertaken (new, redesign, repair/upgrade) to roadways and associated impervious surfaces, these may present opportunities and potential funding to retrofit or introduce GI for infiltrating stormwater.	• What are the missed opportunities for promoting stormwater recharge in the context of transportation projects (new, redesign, repair/upgrade)?
	• What can be done to take advantage of these opportunities at local, state, and federal levels, considering:
	  • Regulatory options.
	  • Non-regulatory options.
	  • Funding/financial options.
		• Take advantage of existing processes, like the health impact assessments done by the Department of Public Health and MassDOT *Storm Water Handbook* update, as places to promote GI.
		• Improve partnering with Massachusetts Emergency Management Agency, MassDOT, and FHWA. Build on Complete Streets work to incorporate green streets, and address concerns about maintenance issues and vegetation management.
		• Consider opportunities in rights of way, medians, parking lots, and sidewalks.
		• Federal Funding Guidelines updated to allow/incentivize porous pavement.
		• Grants: use federal and state grants to promote and incentivize GI.
		• Consider revising state building codes (e.g., minimum road widths).
		• **Partner with the MassDOT and FHWA to increase the opportunities to promote GI as well as the integration of potential projects into state and federal transportation planning. Explore opportunities with other state and federal agencies involved in development.**

Potential Opportunities	Questions to Consider	Workshop Discussion Recommendations (report recommendations in bold)

3. **EDUCATION AND TRAINING—** Where infiltration is an option (for communities complying with WMA, interbasin transfer, or MS4 permits), there may be countervailing pressures to pursue more traditional controls.	• There is a lack of knowledge about GI approaches, confidence in using them, and pressure to use traditional approaches. How do we counteract this?
	• How can municipal officials, the contracting community, and the public be better equipped with the information and tools they need to overcome this lack of confidence in using GI approaches?
		• **Increase confidence in using GI practices through expanded training and education/outreach opportunities.**
		• Consider ways to incentivize the implementation of GI practices across the state:
		  ◦ Share examples of municipal practices and bylaws.
		  ◦ Provide resources to departments of public works (DPWs) so they know how to use, maintain, and implement GI solutions.
		  ◦ Create checklist of maintenance and stewardship for DPWs and training for DPWs. Possibly partner with Bay State Roads for training.
		  ◦ Create toolkit/startup kit.
		  ◦ Define who should provide lead support role—MAPC, New England American Public Works Association.
		• Provide a common central message, with marketing—and identify who would lead this effort and who provides the training (EPA, TPL, and other non-profits?):
		  ◦ Work with various groups to network: trade associations, Massachusetts Farm Bureau, New England American Public Works Association.
		  ◦ MAPC, Highway Director Association.
		  ◦ Integrate university research and practitioners to lead implementation-based training.
		  ◦ Consider a GI certification program.

4. **DESIGN and SITING—**Where infiltration is required or pursued as an option for meeting requirements, it is often designed to discharge as much runoff as possible into the most convenient location for the landowner/developer; these locations may be less than ideal for effective recharge (e.g., distributed recharge). More design guidance and perhaps requirements could result in more effective designs.	• What are ways to get the most effective recharge, distributed on the landscape, in the most effective places? • How can these methods be applied in a way that maximizes flexibility for the permittee?	• Not discussed.

Potential Opportunities	Questions to Consider	Workshop Discussion Recommendations (report recommendations in bold)
5. **STANDARDS AND GUIDANCE**—State stormwater standards are being synchronized with MS4 permits –is this an opportunity to improve infiltration guidance/requirements? One example would be the MS4 permit requirement that MS4 communities identify five locations for stormwater infiltration by June 2019.	• Can the state improve infiltration guidance/requirements (MS4)? • What tools should be promoted (and how) to identify the best sites for infiltration?	• **Align MS4 permit requirements with statewide stormwater standards, and review for consistency as well as potential opportunities for strengthening.** • Assess the standards, clarify some, and address the inconsistency from agency to agency. Highly developed areas do not have requirements, mostly for new construction. o Need uniform standards across programs—WPA, MS4, water management, etc. (currently inconsistent, i.e., greater than/less than XYZ acreage). o May be a difficult and long-term process to change. • **Promote implementation of GI for drought projects and provide technical assistance/ support to local communities, through the MS4 stormwater program's requirement that permittees identify five locations for stormwater infiltration practices.** Communities need assistance and support to identify five locations for GI under MS4—can they possibly work with RPA, watershed groups, non-profits? Include training on use of OPTI tool and GI mapping. • Develop standards to address existing development and redevelopment; they should reference predicative modeling, not just historic modeling, and should be required statewide, not just in WPA-regulated areas.
6. **FINANCIAL/REGULATORY INCENTIVES**—There may be financial or regulatory incentives that can drive increased use of GI for recharge. Can permits be streamlined, can in-lieu-fee programs be considered, can more credits be given, and can other financial/regulatory incentives be designed to drive the regulated community towards GI approaches?	• What incentives can be used to promote GI? • How can permits for GI be streamlined? • Should in-lieu-fee programs be implemented? What are the pros and cons? • Could more credits for recharge be given in regulations, and if so, how would that work?	• **Explore financial incentives for GI projects for drought including in-lieu fee (method for off-site compensatory mitigation by paying into a fund for systematic GI implementation within a watershed).** • GI drought methodology to inform offsets, in-lieu decisions (see recommendations under assessment and mapping tool). • Watershed approach: integrated water resources planning (models, funding). • Hazard mitigation plan: resilience, economic development of farmland.

Potential Opportunities	Questions to Consider	Workshop Discussion Recommendations (report recommendations in bold)
7. **LOCAL ACTION—**Innovation leadership often occurs at the local level. There are examples of where this is occurring (see matrix for partial list). What can be done to leverage these initiatives for broader adoption?	• How can local success stories be leveraged and shared for broader adoption? • What are the best ways to promote the multiple benefits and low cost of using a GI approach? • How can we integrate GI into local hazard mitigation plans?	• Peer-to-peer training is effective and needed. • Increase training opportunities to build "in house" technical capacity. • Promote the concept of an "integrated project team" from the beginning of a project. • Promote the triple bottom line approach and the co-benefits of GI. • Share the assessment methodology as a "Best Practice" appendix in the Statewide Plan for local use.
8. **ASSESSMENT AND MAPPING TOOL**	• How can this tool be shared and used?	• **Identify priority areas for recharge in the state. Using the assessment method presented during the workshop - GIS Methodology to Identify Potentially Suitable GI Infiltration Sites (GIS Methodology)—and other available data and/or methodologies.** • **Identify and promote recharge for mitigation under the Water Management Act (WMA) by incorporating the GIS Methodology into state guidance for WMA permittees.** • Consider how to improve the tool: incorporate agricultural issues, soils data, impervious cover layer; consider site thresholds; consider travel time. • Consider how to use the tool at the watershed or state level and integrate with the SWMI program. • Use the tool to help communities develop a "heat" map for GI sites, for MS4, etc. Turning it into an online automated tool/viewer would help local planners. • TPL tool to be updated to include drought layers.

The following recommendations (bolded in the table) were selected for possible exploration within the State Hazard Mitigation Plan:

1. Identify priority areas for recharge in the state. Using the assessment method presented during the workshop - GIS Methodology to Identify Potentially Suitable GI Infiltration Sites (GIS Methodology)—and other available data and/or methodologies.
2. Identify and promote recharge for mitigation under the WMA by incorporating the GIS Methodology into state guidance for WMA permittees.
3. Align MS4 permit requirements with statewide stormwater standards, and review for consistency as well as potential opportunities for strengthening.

4. Promote implementation of GI for drought projects and provide technical assistance/ support to local communities, through the MS4 stormwater program's requirement that permittees identify five locations for stormwater infiltration practices.
5. Increase confidence in using GI practices through expanded training and education/outreach opportunities.
6. Promote GI practices statewide through incentives and/or through expanding the jurisdictional area of the stormwater standards.
7. Explore financial incentives for GI projects for drought including in-lieu fee (method for off-site compensatory mitigation by paying into a fund for systematic GI implementation within a watershed).
8. Partner with the MassDOT and FHWA to increase the opportunities to promote GI as well as the integration of potential projects into state and federal transportation planning. Explore opportunities with other state and federal agencies involved in development.

VII. Conclusion and Next Steps

Moving forward, EPA and FEMA will work with the state to incorporate the GIS Methodology and recommendations from this effort, as appropriate, into the Massachusetts State Hazard Mitigation Plan, currently in development. Ultimately, this methodology may assist communities in planning for GI implementation, preserving suitable sites, and incorporating GI practices at suitable sites as opportunities arise, which may lead to increased base flows, resilience of water supplies, and aquatic habitats in the face of drought.

For the communities of the Commonwealth of Massachusetts to become more resilient to drought, it is necessary to work across disciplines, and use the best data available to determine how to manage land and water resources in ways that promote the natural hydrologic cycle and promote recharge of groundwater. There are several opportunities identified within this report to help move the state forward in this direction.

VIII. Sources

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IX. Appendix

Appendix A: Matrix of Policies and Regulations Regarding Groundwater Recharge Using Green Infrastructure

PROGRAM	EXPLANATION/OPPORTUNITIES	LIMITATIONS	COMMENTS
Water Management Act MGL 21G 310 CMR 36.00 (MassDEP)	The Water Management Act requires that withdrawals over baseline levels be mitigated to the extent feasible. Two types of mitigation exist, direct and indirect. Direct mitigation includes quantifiable actions (stormwater recharge, infiltration and inflow fixes) and is counted as gallon-for-gallon mitigation. Indirect mitigation includes environmental improvements that will help to compensate for streamflow impacts resulting from withdrawals. The relative value of the indirect credits is determined by a qualitative scoring system. Direct mitigation options are to be explored first. Infiltrating groundwater by disconnecting it from surface water discharge locations using green infrastructure (GI) may be used towards mitigation. Projects dating back to 2005 may be eligible for credits, including land purchased for open space protection or placed under conservation restrictions.	MassDEP does not specify where/how such infiltration needs to occur; it is a local decision. Local officials make the decisions on the type of mitigation, mostly based on cost and their knowledge of/comfort with the options. Contractors and town personnel may not be familiar with GI and therefore may be more inclined towards traditional engineering.	This is a relatively new requirement, so it is too early to assess success. GI infiltration could be more effective if prime sites were identified. More training on the costs, benefits, and design of GI and some local success stories could help speed adoption. Prime spots for infiltration are also valued for their high development potential and are therefore high-priced and hard to purchase.

PROGRAM	EXPLANATION/OPPORTUNITIES	LIMITATIONS	COMMENTS
MS4 permits 314 CMR 9.00 and 10.00	MS4 permits call for infiltration (or retention) of runoff for one inch of rainfall for new development (> 1 acre of land disturbance) and 0.8 inches for redevelopment (> 1 acre of land disturbance). While other standards in the MS4 general permit cross-reference the state's stormwater standards, the retention/infiltration standard in the MS4 permit is generally more stringent than the state's regulations, which are based on a sliding scale according to soil type (rainfall capture ranges from 0.1 to 0.6 inches).	Need to synchronize state and federal regulations. MassDEP is currently working on this. Current methods for calculating runoff are in flux. The infiltration/retention standard only applies to new development and redevelopment within jurisdiction and for land alterations greater than 1 acre. It also does not address the stormwater quality and quantity impacts of existing development. No incentive to get communities or private landowners to improve existing conditions. Water quality controls under MS4 permits can reduce infiltration as an option—applicants can opt to reduce total suspended solids to 90 percent or phosphorus to 60 percent. Where it is easier to meet water quality reductions, infiltration design is likely to be reduced.	By June 30, 2019, MS4 communities are to adopt infiltration standards and by 2021, they are to identify five locations for stormwater infiltration. Providing optimization tools and technical assistance would help communities identify the best locations. Prime spots for infiltration tend to have higher development potential and therefore are higher-priced and hard to purchase. A total maximum daily load (TMDL) or EPA's use of residual designation authority in the Upper Charles Watershed may require retrofits.
U.S. EPA NPDES program	Consider promoting GI in combined sewer overflow plans.	Infiltration sites need to be readily available.	

PROGRAM	EXPLANATION/OPPORTUNITIES	LIMITATIONS	COMMENTS
Underground Injection Control (Safe Drinking Water Act) 310 CMR 27.00 (MassDEP) Title 40 CFR (EPA)	Underground Injection Control regulations cross-reference the stormwater manual and applicable state regulations.	A Class V well permit might be required. The general rule is that if a practice is "deeper than it is wide," it might need a permit.	Opportunities related to infiltrating roof drains.
Massachusetts Wetlands Protection Act MGL 131.40 310 CMR 10.00 (MassDEP and local conservation commissions)	The Massachusetts Wetland Protection Act regulates work within 100 feet of a wetland or other defined resource area. In 2008, MassDEP approved stormwater management standards that would need to be implemented under the Wetland Protection Act. MassDEP is committed to effective stormwater management and has adopted state standards since 1996, making Massachusetts one of the first states to do so. Activities subject to jurisdiction involving stormwater runoff within wetlands jurisdiction must infiltrate at least the first 0.5 inch of runoff, based on soil type, except in critical areas and for land uses with higher potential pollutant load, which require infiltration of 1 inch. Syncing with MS4 standards will strengthen and streamline requirements.	New stormwater management structures are prohibited from all areas subject to protection under the Act, but can be permitted in the buffer zone within the 100-year floodplain, provided performance standards for all resource areas are met. Stormwater management structures are not allowed where infiltration is not likely to function and where impacts would outweigh the benefits. Although low-impact development practices are encouraged, siting/space limitations often result in all stormwater managed at one (low) point on property rather than distributed throughout, which would provide optimal benefits.	Analysis is underway now to develop options for how to synchronize state and federal standards for infiltration (the state can adopt MS4 as is, develop an equivalency method based on soil, or have a separate standard for areas within wetlands jurisdiction vs. urban areas). Further incentivize distributed stormwater recharge designs. Education/training of developers and their engineers. Prime spots for infiltration also have high development potential and are therefore high-priced and hard to purchase.

PROGRAM	EXPLANATION/OPPORTUNITIES	LIMITATIONS	COMMENTS
Massachusetts River Protection Act 310 CMR 10.58	Riverfront Area regulations: The Riverfront Area is 200 feet from the mean annual high water of rivers and > 25 feet in cities and designated "densely developed areas." In these areas, new development is limited to 10 percent of lot size or 5000 square feet. This allows for more flexibility for mitigation/redevelopment. Redevelopment in the Riverfront Area must be an "improvement over existing conditions." This could be an opportunity to promote GI practices.	Local rules can vary and be more prohibitive than state standards. Exemptions to the stormwater management standards include single-family homes, certain housing and redevelopment projects, multi-family developments or redevelopments (four or fewer units), and emergency road repairs. Only applies to new development and redevelopment without addressing stormwater quality and volume problems created by existing development. No incentive to get communities or private landowners to fix or improve upon existing conditions.	A TMDL or EPA's use of residual designation authority in the Upper Charles Watershed can to some degree force retrofits. EPA's MS4 permit will cover some impervious surfaces, but there is likely quite a bit of impervious surface that still falls under the state-level exempt categories outside of MS4s and is therefore unregulated. Stormwater mitigation banking similar to wetland mitigation banking could be considered. Section 404 Wetland permits could promote GI as part of mitigation for the impacts of wetland loss.

PROGRAM	EXPLANATION/OPPORTUNITIES	LIMITATIONS	COMMENTS
Drinking Water (Wellhead Protection Regulations) 310 CMR 22.00: Drinking Water Regulations 310 CMR 22.02, 22.03, and 22.21 (MassDEP) Definitions: **Zone I**: For public wells with approved yields of 100,000 gallons per day or greater, the protective radius is 400 feet. Tubular wells require a 250-foot setback. In no case can the Zone I be less than 100 feet. **Zone A**: Land within 400 feet of the upper boundary of the bank of a surface water source, as defined in 314 CMR 4.05(3)(a); and the land within 200 feet of the upper boundary of the bank of a tributary.	GI recharge incentive provided in the Wellhead Protection (Zone II) Regulations prohibits land uses that result in rendering any lot or parcel impervious more than 15 percent or 2500 square feet, whichever is greater, unless a system for artificial recharge of precipitation is provided *that will not result in the degradation of groundwater quality.* 310 CMR 22.21(2)(b)(7)	Drinking water setback requirements limit stormwater infiltration (stormwater discharge generally prohibited) within: • 100 feet of a private well. • Zone I (generally 400 feet) of public supply wells. • Zone A (generally 400 feet) of surface water reservoirs and within 200 feet of tributaries thereto. From MassDEP's 2008 Stormwater Manual: "Stormwater discharges to a Zone I or Zone A are prohibited *unless essential to the operation of a public water supply.*" Only applies to new development and redevelopment without addressing stormwater quality and volume problems created by existing development. No incentive to get communities or private landowners to fix or improve upon existing conditions.	Drinking water source protection standards (for Zone I/Zone A) are intended to prevent alteration within the most vulnerable areas located closest to the drinking water source, and thus also prevent construction of infiltration devices. These protective zones are not expansive, and the benefits of maintaining the land in as pristine a state as possible generally outweigh the barriers imposed on the siting of GI systems. Infiltration is required within Zone II for any significant land alterations, which is an opportunity for infiltration systems.

PROGRAM	EXPLANATION/OPPORTUNITIES	LIMITATIONS	COMMENTS
Interbasin Transfer Act and Regulations MGL Ch. 21 S. 8 B-D and Regulations 313 CMR 4.00 (MA DCR and Massachusetts Water Resources Commission)	The purpose of the Interbasin Transfer Act is to minimize the transfers among the river basins of the Commonwealth. In 2007, the Water Resources Commission adopted an offsets policy to further that goal by providing a means to avoid or minimize a net interbasin transfer through the application of approved offsets. This mitigation policy allows measurable recharge in the donor basin to help offset the impacts of transfer, lower the threshold for transfer, or condition transfer approvals. Interbasin transfers less than 1 million gallons per day are eligible to apply for a Request for Determination of Applicability where the full volume can be offset (small projects) or for a determination of insignificance, which is subject to several criteria that must be met. Reducing the volume of transfer via a measurable reduction of transfer from the donor basin via offsets can help applicants qualify for this determination.	Mitigation is not required. Stormwater recharge is not specifically mentioned Provision is not used very often, only when applicants want to reduce their impact for regulatory relief or to get below the threshold.	Policies/guidance may be revised, which could present an opportunity to promote GI infiltration.

PROGRAM	EXPLANATION/OPPORTUNITIES	LIMITATIONS	COMMENTS
Water Quality Certification (2008) 314 CMR 9.00 (Mass DEP)	Standards are consistent with the Wetlands Protection Act MGL 131.40. Activities subject to water quality certifications must infiltrate stormwater according to a sliding scale and infiltrate at least the first 0.5 inch of rainfall, based on soil type, except in critical areas and for land uses with higher potential pollutant load, which require an infiltration of 1 inch. Syncing with MS4 standards will strengthen and streamline requirements.	Siting/space limitations often result in all stormwater managed at one (low) point on property rather than distributed throughout, which would provide optimal benefits. Only applies to new development and redevelopment without addressing stormwater quality and quantity impacts of existing development. No incentive to get communities or private landowners to fix or improve upon existing conditions.	Analysis is underway now to develop options for how to synchronize state and federal standards for infiltration (the state can adopt MS4 as is, develop an equivalency method based on soil, or have a separate standard for areas within wetlands jurisdiction vs. urban areas). Prime spots for infiltration also have high development potential and are therefore high-priced and hard to purchase. Consider distributed stormwater recharge designs. Education/training needed. A TMDL or EPA's use of residual designation authority in the Upper Charles Watershed can to some degree force retrofits.

PROGRAM	EXPLANATION/OPPORTUNITIES	LIMITATIONS	COMMENTS
Local ordinances/bylaws	Communities in Massachusetts enjoy "home rule" authority, which gives them wide latitude for enacting bylaws (towns), ordinances (cities), and policies that are more stringent than state or federal standards, so long as they are not considered a "taking." Initiatives are emerging that provide opportunities for communities to take action, should they have the political support to do so (see "comments on overcoming barriers").	Pro-development attitude of local communities; political challenges of balancing private property rights with the public good.	Alliance for Water Efficiency Net Blue Project provides guidance and model ordinances for local water resource sustainability planning. The Town of Acton is participating in developing the Net Blue ordinance toolkit. Massachusetts Audubon created a bylaw matrix as part of its Shaping the Future of Your Community program. Devens Enterprise Commission has infiltration and GI stormwater standards. Open space residential design, smart growth practices, lawn alternatives, and irrigating golf courses with gray water or wastewater (fertigation).

Appendix B: Matrix of Non-Regulatory Opportunities and Limitations Regarding Groundwater Recharge Using Green Infrastructure

PROGRAM	EXPLANATION/OPPORTUNITIES	LIMITATIONS	COMMENTS
Transportation and other development projects	When roads are improved/expanded or repaved, there's an opportunity for stormwater redesign and funding. Update of MassDOT *Storm Water Handbook* with additional guidance on GI practices.	Transportation projects tend to average stormwater requirements over the length of each sub-watershed and are often constrained by available right of way easement. Hard to infiltrate where sites are constrained and poor drainage exists, or where the drainage system is overwhelmed from overdevelopment. Complete streets initiative—adding sidewalks on both sides of roads—is expanding footprint and making it harder to meet standards—need better porous pavement design and training.	Consider distributed (decentralized) systems, and consider offsite mitigation (see below). Consider offsite mitigation in same watershed where sites are more optimal and require a higher mitigation ratio. Improved porous pavement design for sidewalks/lack of awareness. Make this a standard practice through MassDOT funding priorities. Communities are also considering how to make streets "green" and "complete," which includes stormwater management and vegetation.
Massachusetts State Building Code 780 CMR 10.00	Requires minimum road widths for access and egress.	Need to synchronize state and federal Minimum road widths may be excessive and are not flexible enough to allow for alternative designs that could reduce stormwater runoff.	
Professional community of practice	Increase awareness among community developers, planners, and developers' contractors on GI design and construction.	Lack of education/training for GI design/construction (planners, design engineers, contractors).	Incentives for permitting (shorter timelines, etc.). Training sessions for planners on cost-effective GI and a clear path for permitting. Training located at sites where municipal personnel can view practices.

PROGRAM	EXPLANATION/OPPORTUNITIES	LIMITATIONS	COMMENTS
Maintenance	Long-term stormwater operations and maintenance costs for GI infiltration may be less than those of traditional stormwater systems.	Maintenance is always an issue for stormwater systems, but GI requires maintenance practices for which those responsible for maintenance may lack skills and knowledge. Weather conditions (frozen ground conditions) in New England may pose constraints on recharge.	Training sessions for planners on cost-effective GI and a clear path for maintenance. Provide a GI circuit rider. Provide case studies and site visits.
Redevelopment	Much of Massachusetts is developed, and redevelopment is an opportunity to incorporate GI into the design. Some cities have redevelopment requirements that can be waived by contributions to a fund for GI installation.	Expanding redevelopment requirements is typically viewed as anti-business and a financial burden to development.	Consider options for increasing redevelopment requirements for infiltration (e.g., reduce 1-acre threshold to one-half acre for MS4 permits).

PROGRAM	EXPLANATION/OPPORTUNITIES	LIMITATIONS	COMMENTS
Massachusetts Drought Management Plan	Currently, Drought Management Plan actions are being reviewed and revised. There may be an opportunity to add GI to actions.	Purpose of the plan is to: • Coordinate activities in response to drought. • Identify responsibilities for information collection needed to assess the impacts. • Establish a consistent basis for evaluating the severity of drought. • Identify the lines of communications to allow the smooth flow of information. • Summarize the emergency powers available to government agencies to respond to droughts. While nearly half of all Massachusetts communities are participating, it is a voluntary program, and funds can be used for multiple purposes, not just open space. Opportunities for GI would need to be promoted.	Unclear if drought resilience can be incorporated into the plan.
Community Preservation Act MGL CH 44B	Opportunity for communities to opt into the program, which provides funds for open space and other community preservation needs from up to 3-percent surcharge on local property taxes.		

PROGRAM	EXPLANATION/OPPORTUNITIES	LIMITATIONS	COMMENTS
Massachusetts Green Communities Program	This program focuses on energy and climate impacts and could serve as a foundation for a broader green communities initiative.	GI or using it as a model for similar programs targeted to sustainable water resources management.	
Integrated Water Resources Planning	GI can be promoted along with wastewater reuse/recharge, water conservation, and other methods to ensure sustainable water resources management.	While the policy and guidance frameworks are in place, a lack of funding and strong mandate limit implementation opportunities.	
Community participation in the FEMA Community Rating System for Floodplain Management (an incentive program to reduce flood insurance premiums)	If a community exceeds the minimum actions required under the National Flood Insurance Program, they can get “credits” toward reduced policies.	Pro-development attitude of local communities; political challenges of balancing private property rights with the public good.	The Community Rating System is a complicated program and takes a concerted effort on the part of a community to get enough credits. Credits are given for various types of stormwater management, including if credits “require” low-impact development and/or manage stormwater from developed areas (points vary related to amount of area managed).

Appendix C: June 26, 2017, Workshop Participants

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Appendix D: Green Infrastructure for Drought Best Practices

Best Practices

Climate Adaptation and Disaster Mitigation Working in Massachusetts

Siting Green Infrastructure for Drought Resilience

Insert Agency logos (see 2010 Best Practices):

EPA

MA DCR

FEMA

MEMA

etc.

This bioretention system in Lawrence, MA, is an example of green infrastructure installed during the redevelopment of an old school site.

Green Infrastructure (GI) can be designed to infiltrate runoff from developed areas or to preserve the natural infiltration capacity of a site to help communities to be resilient to drought conditions. GI manages the hydrologic impacts of urbanization, land development and redevelopment by mimicking nature in reducing stormwater runoff, reducing pollutants in stormwater, and increasing groundwater recharge.

Where should Green Infrastructure practices be installed to promote infiltration? Sites in the built or natural landscape that are most suitable for enhanced infiltration using GI practices can be characterized by a set of basic criteria. These include soil type, landscape position, depth to groundwater and surficial geology. These criteria can be assessed using a desktop geographic information system (GIS) to create a map of site suitability. Each parcel is scored for each criteria based on ratings created by the user. Additional criteria can be included as needed to meet the goals of the user. The following page presents the suitability assessment process using Milford, MA as an example.

Certain areas where GI should be avoided:

- Shallow Depth to Groundwater
- Shallow Depth to Bedrock
- Within 50-100 feet of a wetland, stream or river
- Near a contaminated site
- Within an inner water supply protection zone

Suitability Assessment Calculation: In this example, some potential GI sites are initially excluded from consideration. These include sites with a depth to groundwater or bedrock of less than 2 feet, within 50 feet of a wetland or 100 feet of a river, within an area with a reported contamination spill or Activity and Use Restriction (AUL), or within water supply protection Zone A or Zone 1 (the innermost zones as regulated in Massachusetts). Site suitability for a parcel is the sum of the ratings, with soils and the regulated waterbodies criteria receiving double weight. Implementation suitability, which considers impervious characteristics, is the sum of the implementation ratings, with all criteria weighted equally. The overall suitability score for a parcel is the sum of these two scores. The ownership of sites (public versus private) was not considered in this assessment, but may also be of interest if a municipality is considering implementing GI projects on public property.

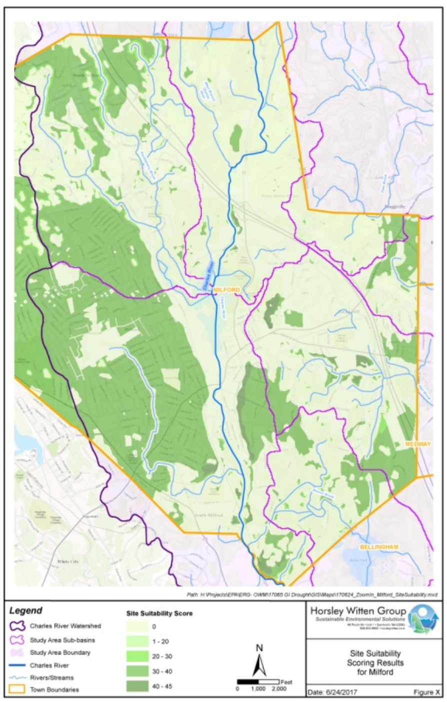
Suggested Site Suitability Criteria:

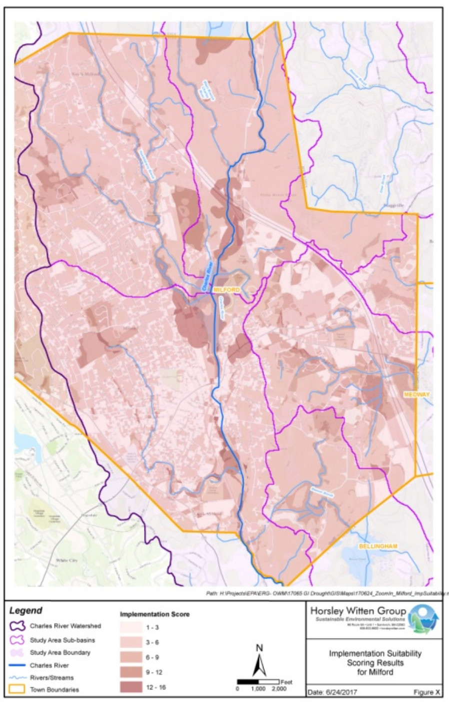
Hydrologic soil group (HSG): *HSG A is the most permeable and HSG D is the least permeable.*
Depth to groundwater/bedrock: *Deeper is better to allow more water to infiltrate into the ground.*
Surficial geology: *This can provide additional information about recharge capacity of a site, especially under soils categorized as Urban Land.*
Buffer to a regulated waterbody: *It can be difficult to work in regulated wetland buffers.*
FEMA flood zone: *These areas are likely to have tight wet soils and a high groundwater table.*
Contaminated sites: *Infiltration in contaminated soils can promote groundwater contamination*
Water stressed basin: *These areas can benefit most from enhanced infiltration.*
Water supply protection zone: *Inner protection zones should be avoided to limit potential contamination. Outer protection zones may be targeted to enhance water supply availability.*

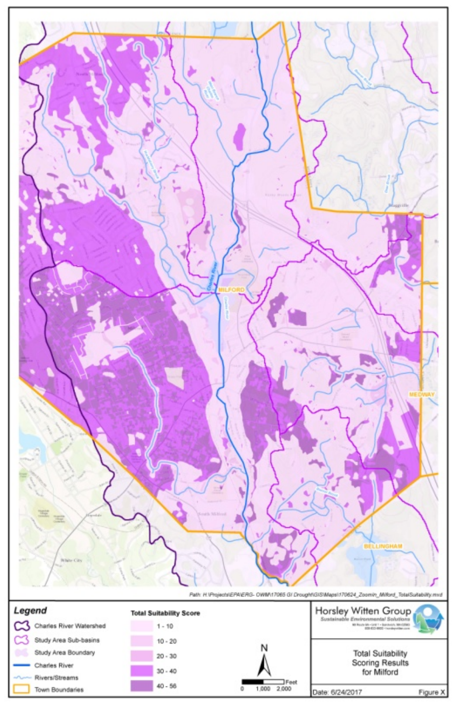
Suggested Implementation Suitability Criteria:

Slope: *A flatter site can more easily slow and infiltrate runoff than a steeper site.*
Onsite impervious area (% of parcel): *This can indicate the availability of space for GI installation.*
Contributing impervious are*a: A site is preferred if it can collect a suitable amount of runoff.*
Contributing impervious area/available area on site: *A ratio of about 3:1 to 20:1 is best suited for GI.*
Existing stormwater basin: *These can be easier to retrofit since water is already draining to them.*

SITE SUITABILITY	+	IMPLEMENTATION SUITABILITY	=	OVERALL SUITABILITY







The darker colored areas in each map represent those that are more suitable for GI infiltration practices.

Important Follow Up to the Desktop Suitability Assessment: The desktop GIS analysis to identify potentially suitable sites for GI infiltration practices is an important first step. This step is generally followed by: 1) Reviewing and refining the desktop site suitability results. 2) Reviewing additional data, such as utility locations, site geometry, and accuracy of the data. 3) Performing site visits to observe conditions on the ground and evaluate the accuracy of the assessment data.

Recharging water into the ground with GI will help Massachusetts be more resilient to drought by supporting future water supplies, stream flow, and soil moisture for crops.