



Healthy Soils Report

Fitchburg-NRWA Watershed-Wide Nature-based Solutions Project

Prepared by Regenerative Design Group

May 14, 2024





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Introduction, Purpose, & Key Findings

Introduction

The communities of Ashburnham, Fitchburg, Leominster, Pepperell, and Groton all occupy land within the Nashua River Watershed. The purpose of the Fitchburg-NRWA Watershed-Wide Nature-based Solutions Project is to identify and plan high-impact Nature-based Solutions (NbS) to increase the climate resilience of these five municipalities in a way that builds social and environmental equity and promotes the health of the larger watershed as a whole.

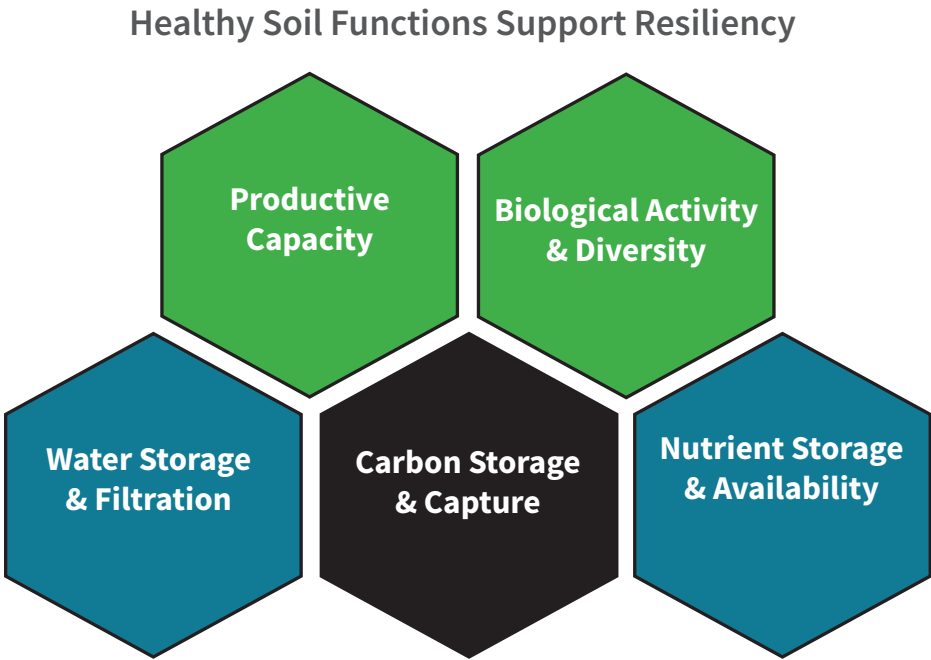
Living soils are the foundation for the ecosystems that shape the character of our communities, enhance the function of our watersheds, support the livelihoods of farmers and foresters, and underpin the rich diversity of life across the terrestrial environment. The Natural Resources Conservation Service (NRCS) defines healthy soils as having "the continued capacity to function as a vital living ecosystem that sustains plants, animals, and humans." Healthy soils, teeming with billions of micro- and macroscopic organisms, provide essential services such as stormwater infiltration, nutrient and water availability, carbon sequestration, plant productivity, water supply protection, erosion protection, and support for insect and disease resistance in plants.

The health of soils and the services they provide are strongly influenced by how people manage and use them, in large part due to the effects of human activity on compaction and soil organic carbon content. Typical construction, landscaping, and farming practices tend to degrade soil health; however, soil-smart land stewardship has the potential to improve soil health and the overall productivity and resilience of natural and human communities.

Understanding the current conditions and types of soils provide guidance on how to protect and regenerate soil health and where nature-based climate solutions could be most effective at realizing the purpose of the Nashua River watershed project.

The following pages contain the findings of an assessment of soil resources and preliminary recommendations for improving soil health structured in three sections:

1. **Soil Functions for Resilience:** A framework for assessing high-impact locations and types of interventions for improved soil health in the five project municipalities.
2. **Planning for Soil Health:** Preliminary recommendations to protect and enhance the soils and ecosystem services they provide in Ashburnham, Fitchburg, Leominster, Pepperell, and Groton.
3. **Soils of Ashburnham, Fitchburg, Leominster, Pepperell, and Groton:** An analysis of the communities' current soil resources and landscape patterns.



The principles, strategies, and actions described in this report can help the five project municipalities protect their natural resources, achieve their goals for climate resilience, win funding for land protection, and guide mandated planning processes. Taking on this work also positions these communities as leaders in implementing the recommendations of the recently published Massachusetts Healthy Soils Action Plan (HSAP).

Improving soil health in these municipalities can also contribute to statewide climate objectives. For example, if the best land management practices were adopted across all land uses at the state scale, enhanced annual natural sequestration could remove an additional 473,000 tons of CO2 from the atmosphere, supporting the no-net carbon emissions goal of the Massachusetts Decarbonization Roadmap.

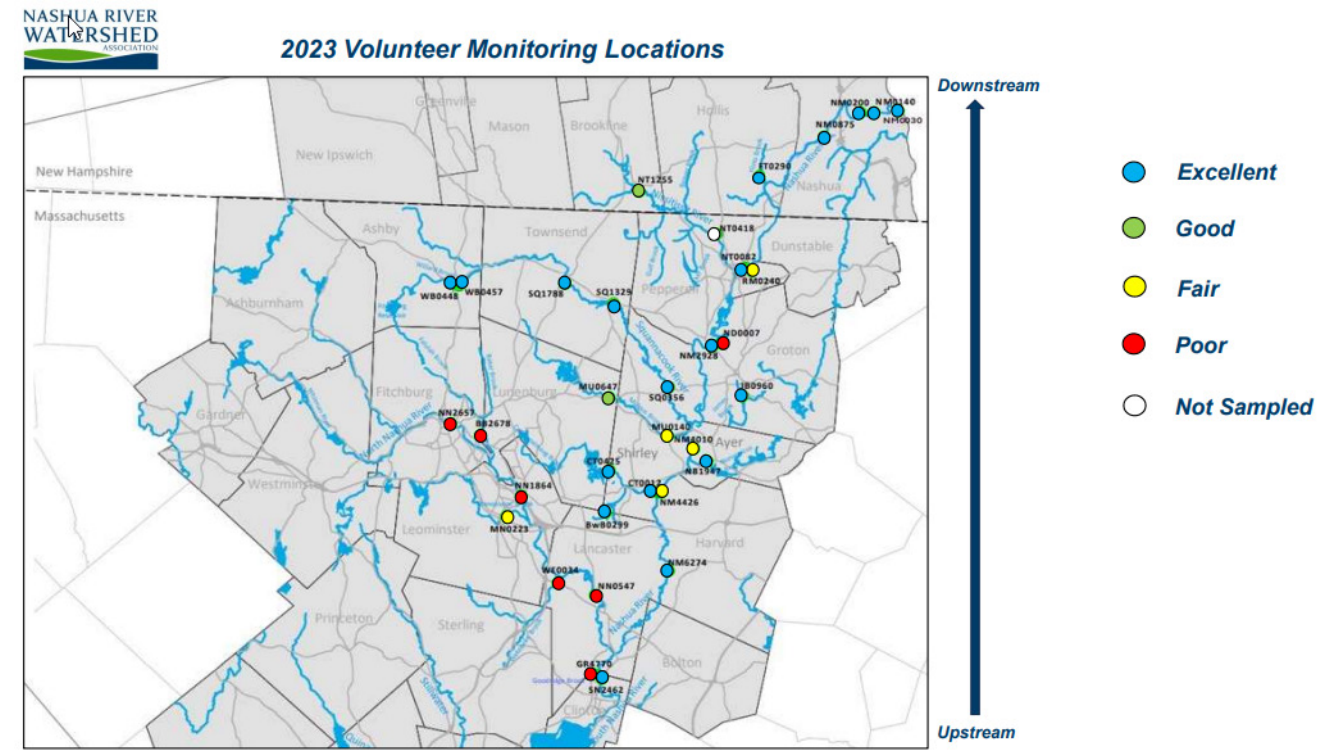
The relevant directives of HSAP include:

- Transform construction practices and requirements to maintain or increase soil health and performance following development;
- Improve soil quality on lands utilized for lawn and gardens, public and private forests, parks and other open or green spaces and non-paved outdoor areas of residences, office complexes, mixed-use facilities, businesses, commercial farms, industries and colleges and other institutions;
- Increase carbon sequestration or storage on such lands to help reduce harmful atmospheric greenhouse gases and the effects of climate change; and
- Enhance soil function such as plant growth, erosion control, nutrient holding capacity, and water absorption and quality on all land cover types.

This project identified ways land managers, residents, and administrative officials can work together to improve soil health, reduce climate vulnerability, and increase the resiliency of the Nashua River Watershed. To best protect the vitality and productivity of the communities' soils and achieve these aims, it will be essential to promote:

- **Conservation, climate-forward management, and active restoration of wetlands and forests, with focused protection of soils at high risk of degradation or development**
- **Better soil management on turf, lawns, gardens, and farms**
- **Regeneration or replication of lost soil function in highly degraded urbanized landscapes**

Where and how to achieve these actions can be informed by the analyses and recommendations in this soil report.



Results from the Nashua River Watershed Association's 2023 E. coli Report Card. Many of the recommendations for improving in-stream water quality, such as increasing vegetated buffers along streams, protecting and restoring wetlands, and following BMP's for lawns and turf, have interconnected soil health benefits like increased carbon sequestration and greater water holding capacity.

Soil Functions for Resilience

Soil organic carbon (SOC) is a key indicator of many of the most important **soil functions**, such as water holding capacity, water filtration, and vegetative productivity. Soil texture plus drainage conditions (think sandy loam with a high water table) control the inherent carbon storage potential of any soils. What covers that soil (like forest, lawn, or asphalt) and how it is managed determine if that soil is living up to its carbon storage potential.

This relationship between a soil's carbon potential and its current carbon holdings informs the distinction between **soil health** and **soil function**. A very sandy soil with good vegetative cover may not be storing much carbon, but it may be maximizing its potential and therefore be considered "healthy." A highly disturbed site with clayey soils may contain more carbon and therefore have greater function than the sandy site yet is likely under performing considering its potential and thus considered to have "low health."

In general, undisturbed, wetter soils with older forests growing on them tend to maximize soil carbon because wet conditions and abundant leaf litter build organic matter over time. More frequently disturbed, sandy, drier soils—like some croplands—tend to store less carbon than is possible because there is less opportunity to build up and stabilize organic matter, which tends to oxidize more quickly when tilled. Through an analysis of soil types and landcover that draws on research-based SOC averages, four classes of Soil Functions for Resilience were identified in the project municipalities. These classes, how much land they include, and planning actions are described below.

High Performance Soils & High Carbon Soils
(145,691 acres)

This category indicates the highest functioning soils and likely high existing SOC stocks. The networks of wetlands and larger patches of forest represent the watershed's major repositories of soil carbon. Protecting these lands preserves these enormous stocks of soil carbon and the tremendous stormwater storage and filtration this offers. Preventing disturbance also maintains the irreplaceable sequestration capacity of these powerful carbon pumps. **See recommendations for increased protection and climate-forward management of wetlands and forests on page 20.**

Moderate-Low Function Soils
(103,909 acres)

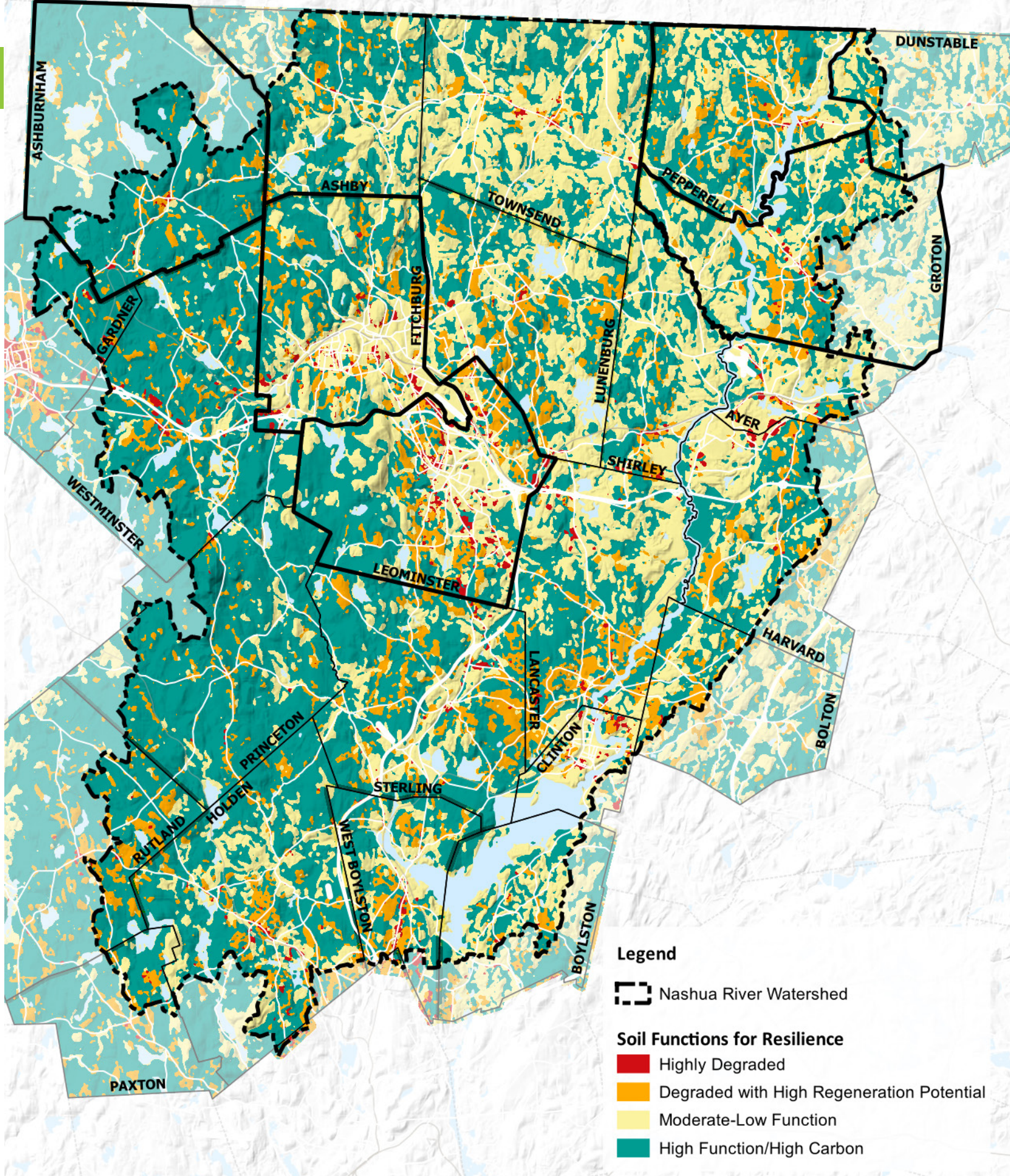
This category indicates moderate to low SOC storage potential and moderate to low existing stocks. These areas are often adjacent to and interspersed with the high carbon holding soils of the forested landscapes. Management should focus on maintaining or increasing soil carbon, primarily through less frequent disturbance and healthy soils practices. **See recommendations for better management of turf, lawns, gardens, and farms on page 22.**

Degraded Soils with High Regeneration Potential
(31,717 acres)

This category indicates high SOC storage potential yet low existing stocks due to land use history. These areas are often found adjacent to highly developed and degraded landscapes. Actions should be taken to restore perennial vegetation and historic hydrology on these landcovers. Wetland restoration, reforestation, decompaction, and agroforestry may be critical strategies to consider. On landscaped or agricultural lands in this classification, a focus on better management to increase soil health and function can have a high impact. Soil-smart practices would focus on limiting disturbance like tillage to encourage deeper, more persistent rooting. This not only minimizes erosion and compaction, but increases the capture and storage of carbon, water, and nutrients in the soil. **See recommendations for better management of turf, lawns, gardens, and farms on page 22.**

Highly Degraded Soils
(4,333 acres)

This category indicates heavily disturbed soils that are high in impervious surfaces on soils with relatively high functional potential. Large scale rehabilitation of soil function in these areas would require a major expenditure of energy and resources but targeted measures can have high ecological value. Intensively designed nature-based solutions like stream daylighting, dam removal, wetland construction, and parking lot forest plantings are potential options for increasing ecological function. Where future construction takes place, use the opportunity created by that disturbance to increase the performance of these soils (see "soil-smart construction and development patterns" on page 15). Consider allowing transfers of development rights to increase density on these soils. **See recommendations for regenerating or replicating lost soil function in highly degraded urbanized landscapes on page 27.**



	ASHBURNHAM	FITCHBURG	LEOMINSTER	PEPPERELL	GROTON	ENTIRE NASHUA RIVER WATERSHED
High Performance Soils & High Carbon Soils	21,170 ac (80.8%)	7,369 ac (41%)	7,821 ac (41.2%)	6,811 ac (45.9%)	8,314 ac (38.5%)	145,691 ac (51%)
Moderate-Low Function Soils	3,450 ac (13.2%)	7,952 ac (44.2%)	7,489 ac (39.4%)	6,039 ac (40.7%)	11,315 ac (52.3%)	103,909 ac (36.4%)
Degraded Soils with High Regeneration Potential	1,507 ac (5.7%)	2,064 ac (11.5%)	2,628 ac (13.8%)	1,893 ac (12.8%)	1,849 ac (8.6%)	31,717 (11.1%)
Highly Degraded Soils	83 ac (0.3%)	609 ac (3.4%)	1,055 ac (5.6%)	101 ac (0.7%)	138 ac (0.6%)	4,333 (1.5%)

Acreage and percentage do not include water body areas.

Watershed-wide Patterns

The Nashua River Watershed is rich in high functioning soils that contain huge amounts of soil carbon (20,316,810 metric tons stored in the watershed's Forests and Wetlands) with the potential to sequester even more. More than half of the watershed area is in the "high function/high carbon" class. The western and southern regions of the watershed are where the most contiguous and abundant healthy soils are found. These regions also represent the watershed's highest elevations, which gives further importance to their soil's capacity to prevent problems downstream, like flooding and poor water quality. Notably, Ashburnham has 21,170 acres of high function/high carbon soils, almost three times the average of the other project communities.

The development and land use patterns of this region have likely degraded much of the soil function on farms, in residential areas, and in urban town centers. Many of these degraded areas are sited on soils that have a high potential for water and carbon storage based on their inherent properties, but management practices are limiting that potential. In the Nashua River Watershed there are a total 31,717 acres of "degraded soils with high regeneration potential". These are found mostly on the farms and residential yard landscapes throughout the watershed and are in abundance in the moderate and lower density zones surrounding Fitchburg and Leominster's city centers. There are also concentrations of high potential soil along the Nashua River just north of the Wachusett Reservoir on the significant agricultural lands of Sterling and Lancaster.

Throughout the northwest half of the watershed, Moderate-Low functioning soils predominate. These are soils with inherent properties that limit their potential to store and filter water and hold on to carbon among other functions. Better management of these soils can maximize their potential and can have a large impact, but these soils may not be considered a priority for regeneration.

Fitchburg and Leominster have the largest amounts of impervious surface and highly degraded soil in the watershed, significantly higher than the watershed-wide average. Their downtown areas sit alongside the North Nashua River and have major effects on water quality and levels downstream. Efforts to regenerate or replicate lost soil function here will require intensive and likely costly interventions.

High Performance Soils & High Carbon Soils (145,691 acres)

High functioning soils with high existing SOC stocks.

The extensive network of wetlands and the hillier, higher elevation areas that are home to larger patches of forest represent the communities' major repositories of soil carbon. These lands provide many ecosystem services and contribute to both local and regional function and resilience.

PRIORITY ACTIONS: INCREASED PROTECTION AND CLIMATE FORWARD MANAGEMENT OF WETLANDS AND FORESTS.

Example Nature Based Solutions:

- Land acquisition
- Proactive tree planting to increase stocking and preserve forest structure
- Improving local bylaws for wetland protections
- Restoring historic wetlands and hydrology
- Proforestation

Moderate-Low Function Soils (103,909 acres)

Moderate to low existing SOC stocks and potential due to inherent properties and land use.

These areas are often adjacent to and interspersed with the high carbon holding soils of the forested landscapes. Management should focus on maintaining or increasing soil carbon, primarily through less frequent disturbance and healthy soils practices.

PRIORITY ACTIONS: BETTER MANAGEMENT OF TURF, LAWNS, GARDENS, AND FARMS.

Example Nature Based Solutions:

- Front yard pollinator meadows
- Dual use solar
- Planning and zoning to preserve and enhance ecosystem function
- Rain gardens
- Best management practices for lawns, turf, and landscaping
- Proforestation

Degraded Soils with High Regeneration Potential (31,717 acres)

Low existing SOC stocks due to land use history with inherently high SOC storage potential.

These areas are often found adjacent to highly developed and degraded landscapes. Actions should be taken to restore perennial vegetation and historic hydrology on these landcovers. Wetland restoration, reforestation, decompaction, and agroforestry may be critical strategies to consider.

PRIORITY ACTIONS: BETTER MANAGEMENT OF TURF, LAWNS, GARDENS, AND FARMS.

Example Nature Based Solutions:

- Education and outreach to key landowners and farmers about smart soil practices
- Pocket forests to increase biodiversity
- Planting and earthworks to restore connectivity and hydrology
- Wetland restoration
- Riparian reforestation

Highly Degraded Soils (4,333 acres)

Highly disturbed soils that are high in impervious surfaces.

Large scale rehabilitation of soil function in these areas would require a major expenditure of energy and resources but targeted measures can have high ecological value. Intensively designed nature-based solutions like stream daylighting, dam removal, wetland construction, and parking lot forest plantings are potential options for increasing ecological function.

PRIORITY ACTIONS: REGENERATE OR REPLICATE LOST SOIL FUNCTION IN HIGHLY DEGRADED URBANIZED LANDSCAPES.

Example Nature Based Solutions:

- Green Infrastructure (high performance tree pits, bio-swales, rain gardens)
- Parking lot renovations
- Stream daylighting
- Dual use and other utility scale solar

Ashburnham

Large amounts of high functioning soil and its position high in the watershed highlight the importance of protecting soil health in Ashburnham.

Ashburnham stands out among the five focus communities as having a particularly large acreage of high functioning soils that are storing over 2 million metric tons of soil organic carbon (SOC). The richest deposits of SOC are found in the wetland systems that extend from the town's major lakes. The 21,170 acres of "high function/high carbon" soils represent 80% of the town's land area and is about 3 times as much area of high functioning soil as the average in the other 4 towns. Ashburnham straddles two major watersheds with the lands to the southeast of town ultimately draining to the Nashua River, and this position highlights the town's importance in protecting and managing soil health to prevent unwanted downstream effects like flooding and poor water quality. Compared to the other four focus communities, the town has limited areas of degraded soils with potential for regeneration (just 5.7% of the land area is classified as having high regeneration potential because of the relatively little soil disturbance in Ashburnham).

Sites Considered for Nature-based Solutions

Despite having such large area of high functioning soil, several sites that see seasonal flooding have been identified in this project. The sites selected for potential Nature-based Solutions are largely nearby water bodies or streams in areas where soil function has been degraded. Efforts to increase soil capacity to store or slow stormwater flow in these locations may have a positive impact and be important demonstration sites. These site specific interventions should be complemented by efforts to conserve and protect important healthy soil resources throughout the town's forested uplands and the wetlands

extending from the town's large water bodies.

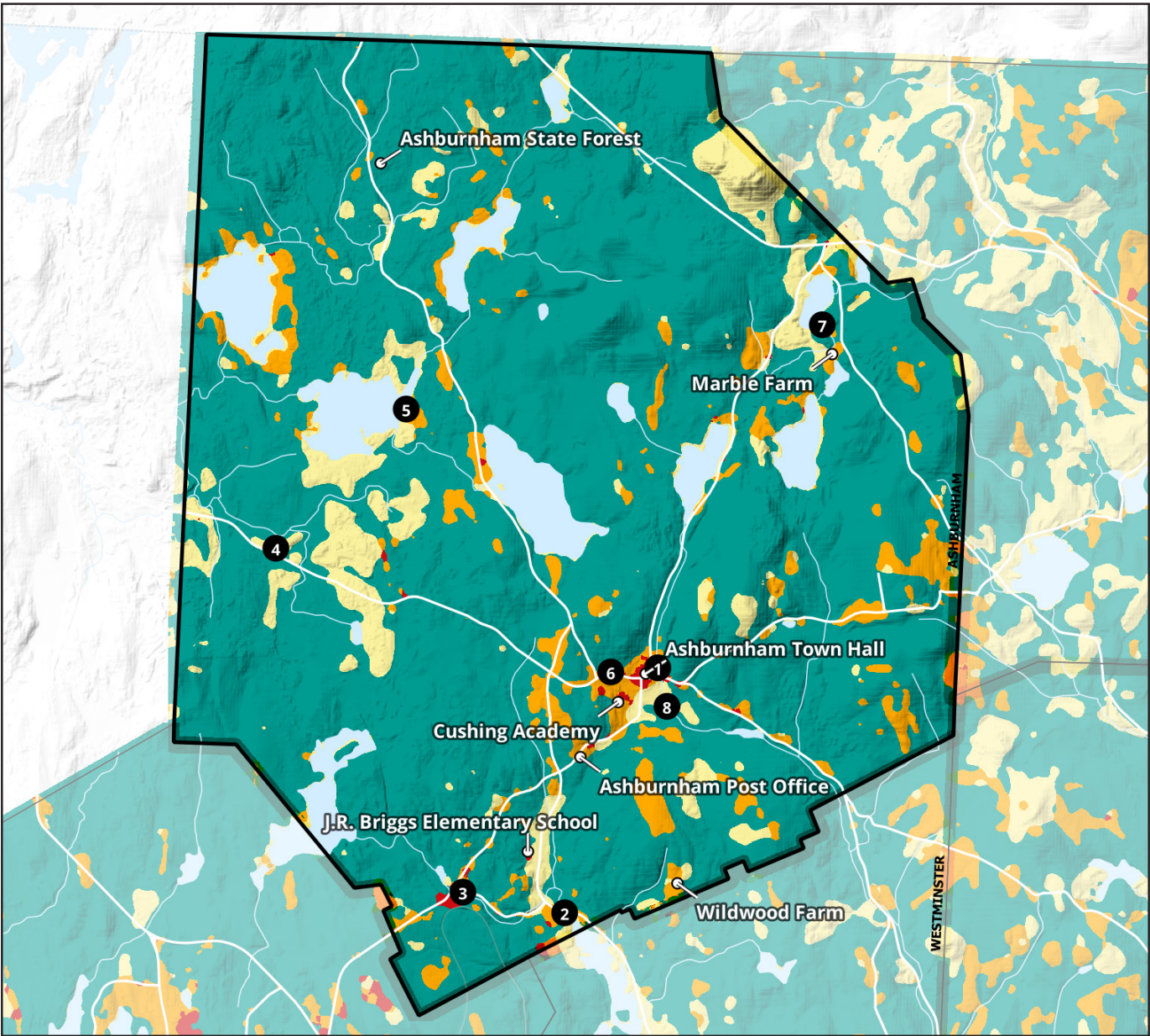
Priority Actions for Protecting/Enhancing Soil Health in Ashburnham

Increased protection and climate forward management of wetlands and forests.

Example Nature-based Solutions:

- Land acquisition and conservation easements
- Forested upland protection district (see Deerfield example, appendix 1)
- Transfer of development from rural to infill locations, including across town borders (See Deerfield example, appendix 1)
- Forest tree planting to increase climate-adapted species abundance and total stock and to preserve forest structure
- Improving local bylaws for wetland protections

Soil Functions for Resilience



#	SITE	PREDOMINANT SOIL FUNCTIONS FOR RESILIENCE			
		Highly Degraded	High Regeneration Potential	Moderate-Low Function	High Function
1	Phillips Brook/Residential Area on Main St.	◆	◆		◆
2	Pump Station			◆	
3	Sweeney Park	◆	◆		
4	Dump/Transfer Station			◆	
5	Page Ave		◆		
6	High St./Cushing St.	◆	◆		
7	S. Branch Souhegan River		◆		◆
8	Brickford Field			◆	◆

	ASHBURNHAM
High Performance Soils & High Carbon Soils	21,170 ac (80.8%)
Moderate-Low Function Soils	3,450 ac (13.2%)
Degraded Soils with High Regeneration Potential	1,507 ac (5.7%)
Highly Degraded Soils	83 ac (0.3%)

- Landmarks
- 1 Sites Considered for Nature-based Solutions

Fitchburg

Significant acreage of degraded soils and soils with high regeneration potential that are spread throughout the city mean that better management practices and efforts to replicate lost soil function are important for increasing resilience in Fitchburg.

Fitchburg, along with neighboring Leominster, contains significant areas of developed and impervious landscapes compared with other communities in the Nashua River Watershed. Much of the most developed and degraded landscapes are found along the North Nashua River that flows through the city center. Pockets of "Highly Degraded" soils that have the potential for restored function with intensive intervention strategies are found throughout this central corridor along the river. The high functioning soils of Fitchburg are found primarily in the forested uplands in the northern half of the city with pockets of "high regeneration potential" soils located on the farmland and residential areas there.

Sites Considered for Nature-based Solutions

Sites of interest for this project are located in the more degraded and low functioning soil areas and subbasins with a focus on green infrastructure to replicate soil water filtration and holding capacity. This is an important strategy; however, paying attention to the areas of high regeneration potential on the farms, lawns, and gardens of the city's upland areas and encouraging management for better soil health there should be a complimentary strategy.

Priority Actions for Protecting/Enhancing Soil Health in Fitchburg

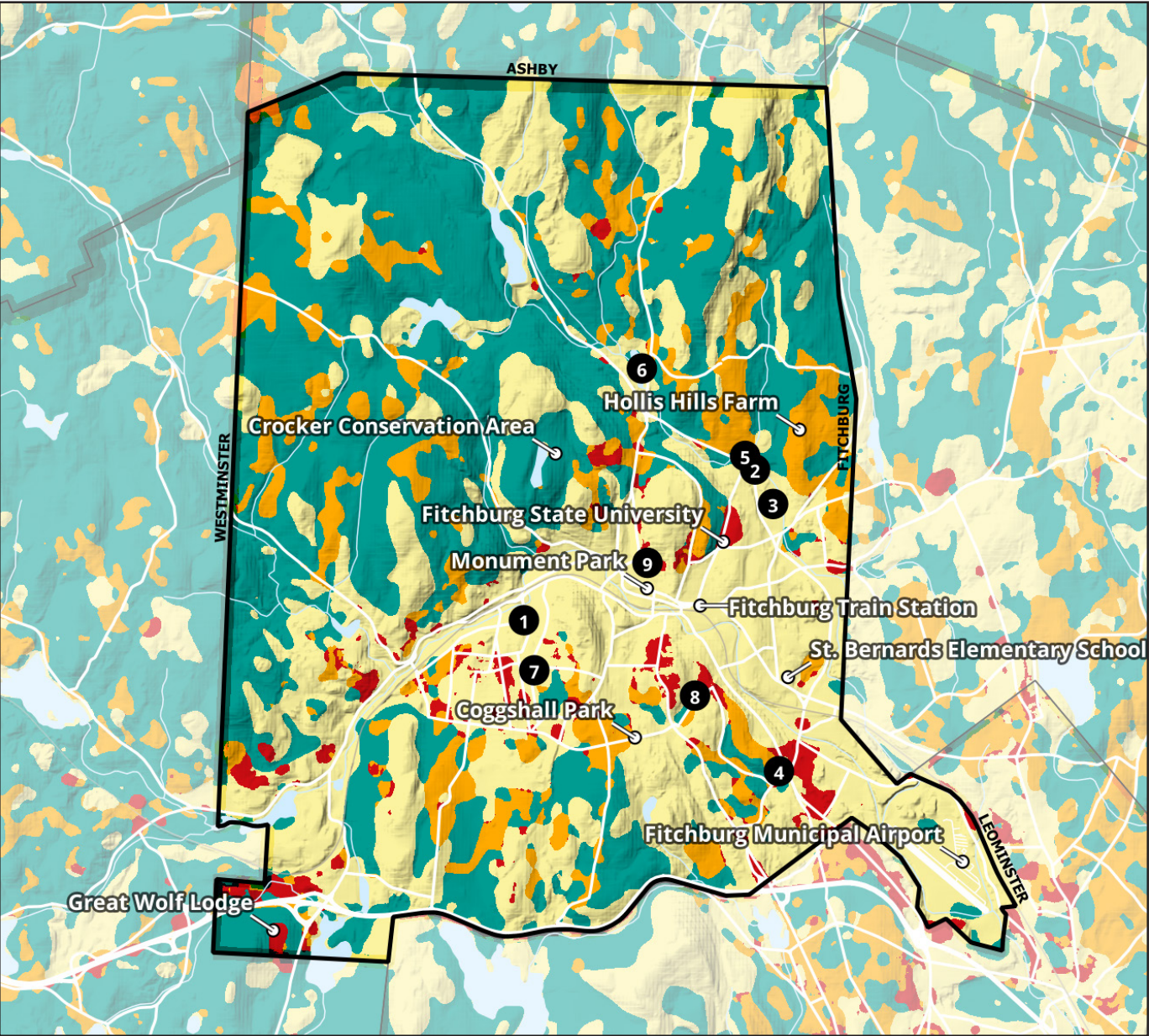
Better management of turf, lawns, gardens, and farms.

- Example Nature-based Solutions:
- Education and outreach to key landowners and farmers about smart soil practices
 - Pocket forests to transform biodiversity
 - Planting and earthworks to restore connectivity and hydrology
 - Front yard pollinator meadows
 - Dual use solar
 - Planning and zoning to preserve and enhance ecosystem function

Regenerate or replicate lost soil function in highly degraded urbanized landscapes.

- Example Nature-based Solutions:
- Green Infrastructure (high performance tree pits, bio-swales, rain gardens)
 - Parking lot renovations
 - Stream daylighting

Soil Functions for Resilience



	Fitchburg
High Performance Soils & High Carbon Soils	7,369 ac (41%)
Average Function Soils	7,952 ac (44.2%)
Degraded Soils with High Regeneration Potential	2,064 ac (11.5%)
Highly Degraded Soils	609 ac (3.4%)

- Landmarks
- 1 Sites Considered for Nature-based Solutions

Leominster

Leominster's soils of high regeneration potential form a belt around the downtown area and are more clustered together than neighboring Fitchburg's. Regeneration or replication of the degraded soil function can mitigate negative impacts to Leominster's downtown and to the communities downstream.

Leominster, like neighboring Fitchburg, contains significant areas of developed and impervious landscapes compared with other communities in the Nashua River Watershed. Much of the most developed and degraded landscapes are found along the North Nashua River that flows in from northern neighbor Fitchburg. Pockets of "Highly Degraded" soils that have the potential for restored function with intensive intervention strategies are found throughout this central corridor along the river. Of the five focus communities, Leominster contains the most acreage of "degraded soil with high regeneration potential" primarily found in the suburban belt that surrounds the more urbanized downtown. The forested upland western side of town is home to the highest functioning soils in Leominster.

Sites Considered for Nature-based Solutions

Several sites in downtown Leominster near the North Nashua river have been identified as flood prone. Efforts to improve soil function in the suburban belt that surrounds the downtown can slow stormwater flows mitigate flooding. Potential sites for this kind of Nature-based Solution are Smith St. and Pierce Pond. Educational projects could be implemented there to encourage better soil management practices on the lawns and gardens of these suburban yards. Notably, there are several sites flagged for potential stormwater catchment projects that are in the same subbasin of the identified flood sites in Ashburnham and upstream of those sites. Sites in the forested uplands should be conserved/reinforced.

Priority Actions for Protecting/Enhancing Soil Health in Leominster

Better management of turf, lawns, gardens, and farms.

Example Nature-based Solutions:

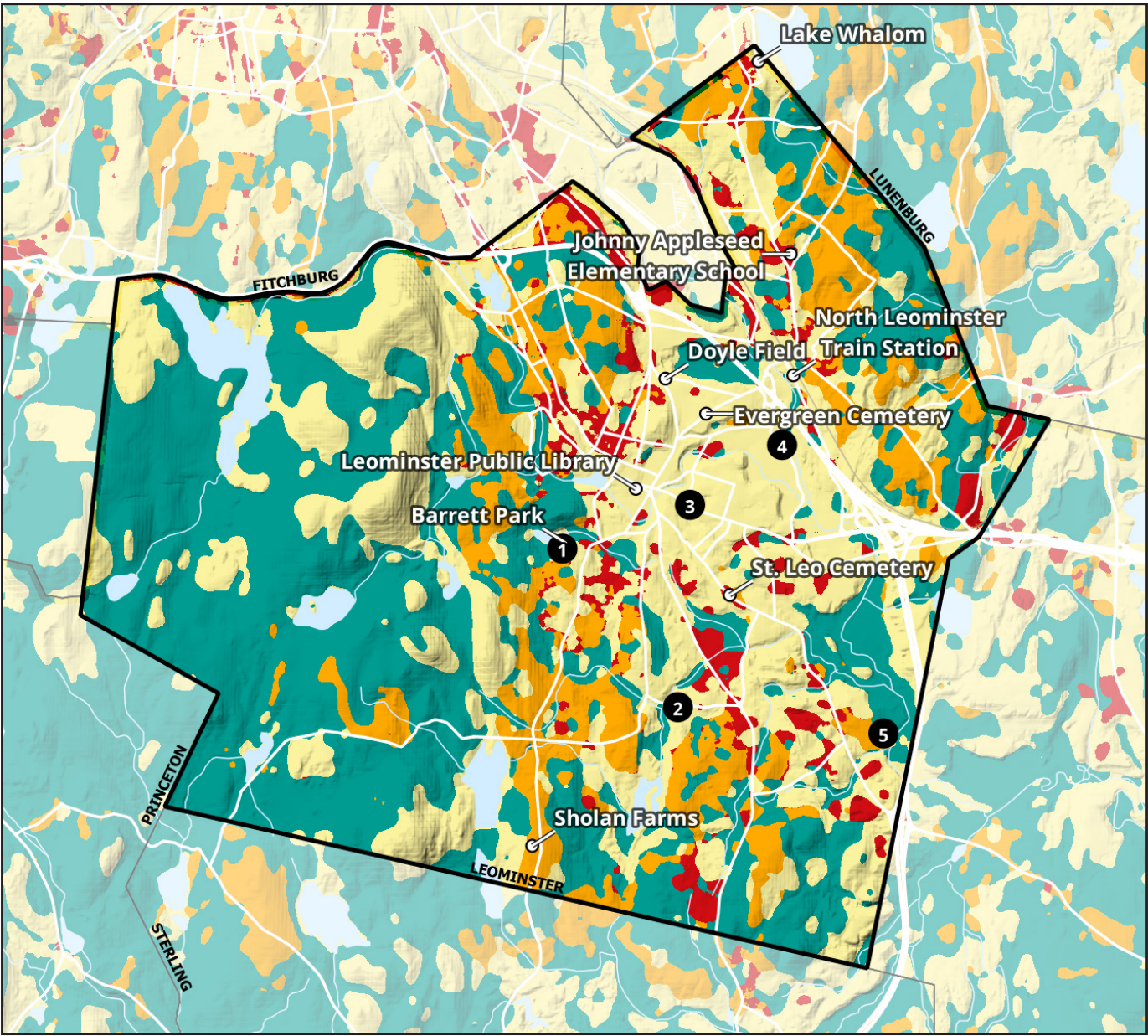
- Education and outreach to key landowners and farmers about smart soil practices
- Pocket forests to transform biodiversity
- Planting and earthworks to restore connectivity and hydrology
- Front yard pollinator meadows
- Dual use solar
- Planning and zoning to preserve and enhance ecosystem function

Regenerate or replicate lost soil function in highly degraded urbanized landscapes.

Example Nature-based Solutions:

- Green Infrastructure (high performance tree pits, bio-swales, rain gardens)
- Parking lot renovations

Soil Functions for Resilience



#	SITE	PREDOMINANT SOIL FUNCTIONS FOR RESILIENCE			
		Highly Degraded	High Regeneration Potential	Moderate-Low Function	High Function
1	Barrett Park			◆	◆
2	Fournier Ballfields			◆	
3	Mechanic St.			◆	
4	Mall Area			◆	
5	Johnny Appleseed SP (DCR)		◆		◆

	Leominster
High Performance Soils & High Carbon Soils	7,821 ac (41.2%)
Average Function Soils	7,489 ac (39.4%)
Degraded Soils with High Regeneration Potential	2,628 ac (13.8%)
Highly Degraded Soils	1,055 ac (5.6%)

- Landmarks
- 1 Sites Considered for Nature-based Solutions

Pepperell

With a position low in the watershed, Pepperell's farmland and suburban residential lands have major potential for better management for increased soil function that would mitigate stormwater issues and benefit the several towns downstream.

Of the five focus communities, Pepperell is "lowest" in the watershed and receives stormwater impact from a vast upland land area. The Nashua River runs along the town's southeastern border and then through the center of town before continuing north. The rich alluvial soils of this riverside community are home to significant acreage of farmland with interspersed residential neighborhoods that constitute a large portion of Pepperell's "degraded soils with high regeneration potential". Compared with other focus communities like Fitchburg and Leominster, Pepperell has a low amount of "highly degraded" soil that would need intensive intervention to replicate lost soil function. The town's acreage of High Functioning soil is below the watershed-wide average, but is still significant and protection of these lands is important for watershed health. These high-functioning soils are evenly mixed with "moderate-low function" soil throughout the town.

Sites Considered for Nature-based Solutions

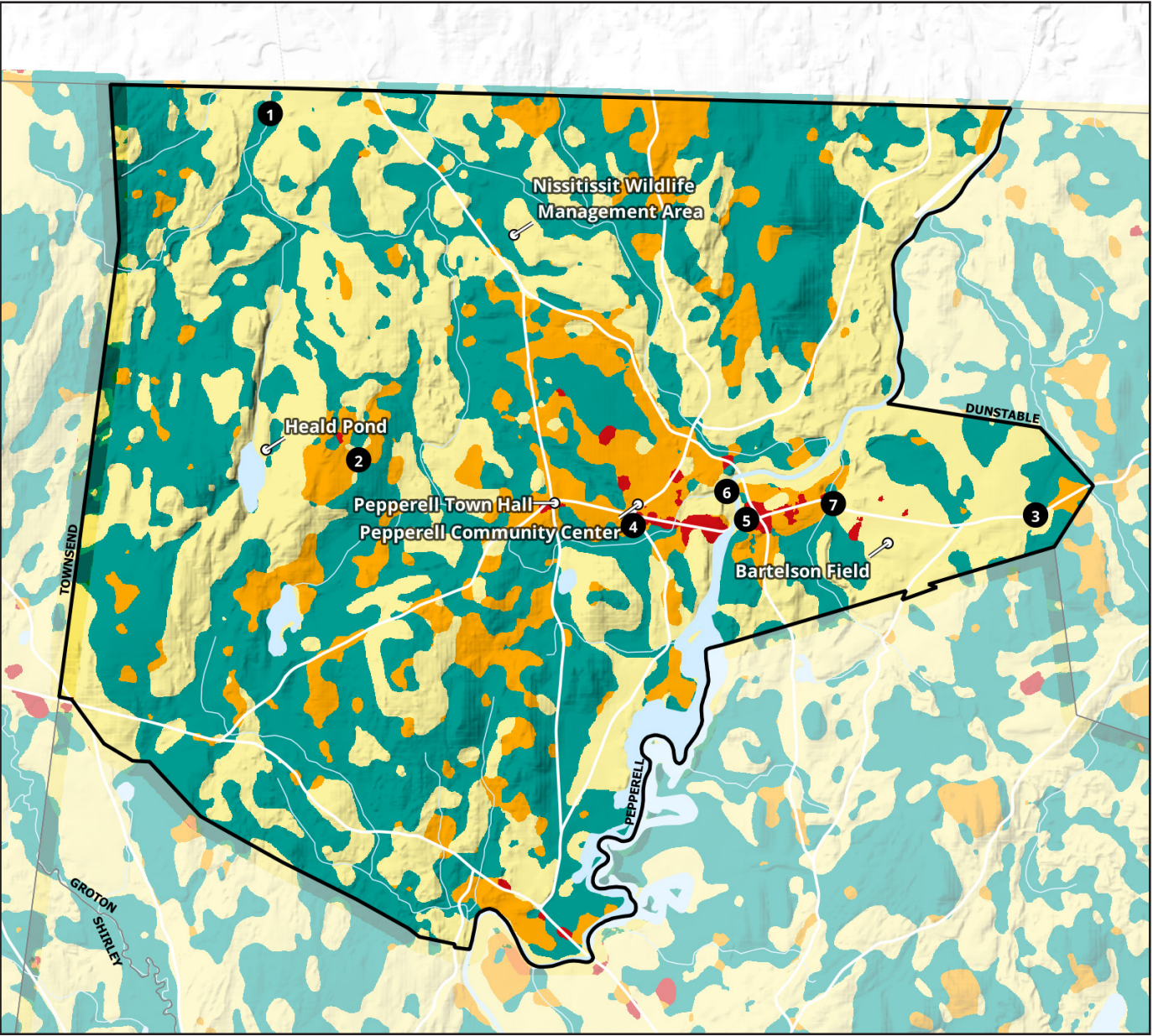
At least two of the sites being considered for stormwater mitigation are on soils with "high regeneration potential" and these sites could be priorities for implementing and tracking the performance of soil-regeneration measures. The Unkety Brook site has been identified as prone to flooding but is within a subbasin that is mostly in neighboring Dunstable.

Priority Actions for Protecting/Enhancing Soil Health in Pepperell

Better management of turf, lawns, gardens, and farms.

- Example Nature-based Solutions:
- Education and outreach to key landowners and farmers about smart soil practices
 - Pocket forests to transform biodiversity
 - Planting and earthworks to restore connectivity and hydrology
 - Front yard pollinator meadows
 - Dual use solar
 - Planning and zoning to preserve and enhance ecosystem function

Soil Functions for Resilience



#	SITE	PREDOMINANT SOIL FUNCTIONS FOR RESILIENCE			
		Highly Degraded	High Regeneration Potential	Moderate-Low Function	High Function
1	Bemis Wellhead Protection Zone/Gulf Brook		◆	◆	◆
2	Heald Orchard/Heald Pond		◆		◆
3	Unkety Brook		◆	◆	◆
4	Fitzpatrick School Parking	◆	◆		
5	Railroad Square	◆	◆		
6	Mill Street/Varnum Brook			◆	
7	Reedy Meadow off Lowell Rd.		◆	◆	◆

	Pepperell
High Performance Soils & High Carbon Soils	6,811 ac (45.9%)
Average Function Soils	6,039 ac (40.7%)
Degraded Soils with High Regeneration Potential	1,893 ac (12.8%)
Highly Degraded Soils	101 ac (0.7%)

- Landmarks
- 1 Sites Considered for Nature-based Solutions

Groton

The significant acreage of soil with high regeneration potential that surrounds downtown Groton and drains to the close by Nashua River could act as key demonstration sites for improved soil practices.

The Nashua River flows northward towards Pepperell on the west side of Groton. A major watershed boundary splits the town, with a large area draining to the Nashua River and another to the Merrimack River. The side of town that drains to the Nashua River contains the community's most significant acreage of farmland and residential neighborhoods as well as most of downtown Groton. These areas are where Groton's acres of "high regeneration potential" soil are found. A key objective for stewarding healthy soils in Groton should be encouraging better management of these degraded lands through education and demonstration projects. Of the five focus communities, Groton has the lowest percentage of "high function/high carbon" soils and the highest percentage of "moderate-low function" soil.

Sites Considered for Nature-based Solutions

Several sites near downtown Groton are being considered for green infrastructure to improve stormwater management. These sites are in areas with "high regeneration potential" soils and could be key demonstration sites for better soil practices. Flooding has been identified at sites throughout the town. Regenerating water holding capacity on soils within the same sub-basins as these flood prone areas is an important planning approach to mitigate these issues.

#	SITE	PREDOMINANT SOIL FUNCTIONS FOR RESILIENCE			
		Highly Degraded	High Regeneration Potential	Moderate-Low Function	High Function
1	Broad Meadow		◆	◆	
2	Groton Country Club	◆	◆	◆	
3	Nod Road			◆	
4	Middle School Parking	◆			
5	Cow Pond Brook/Playing Fields & Highway Dept.			◆	
6	Willowdale		◆	◆	◆
7	James Brook				◆
8	Groton Town Hall	◆			

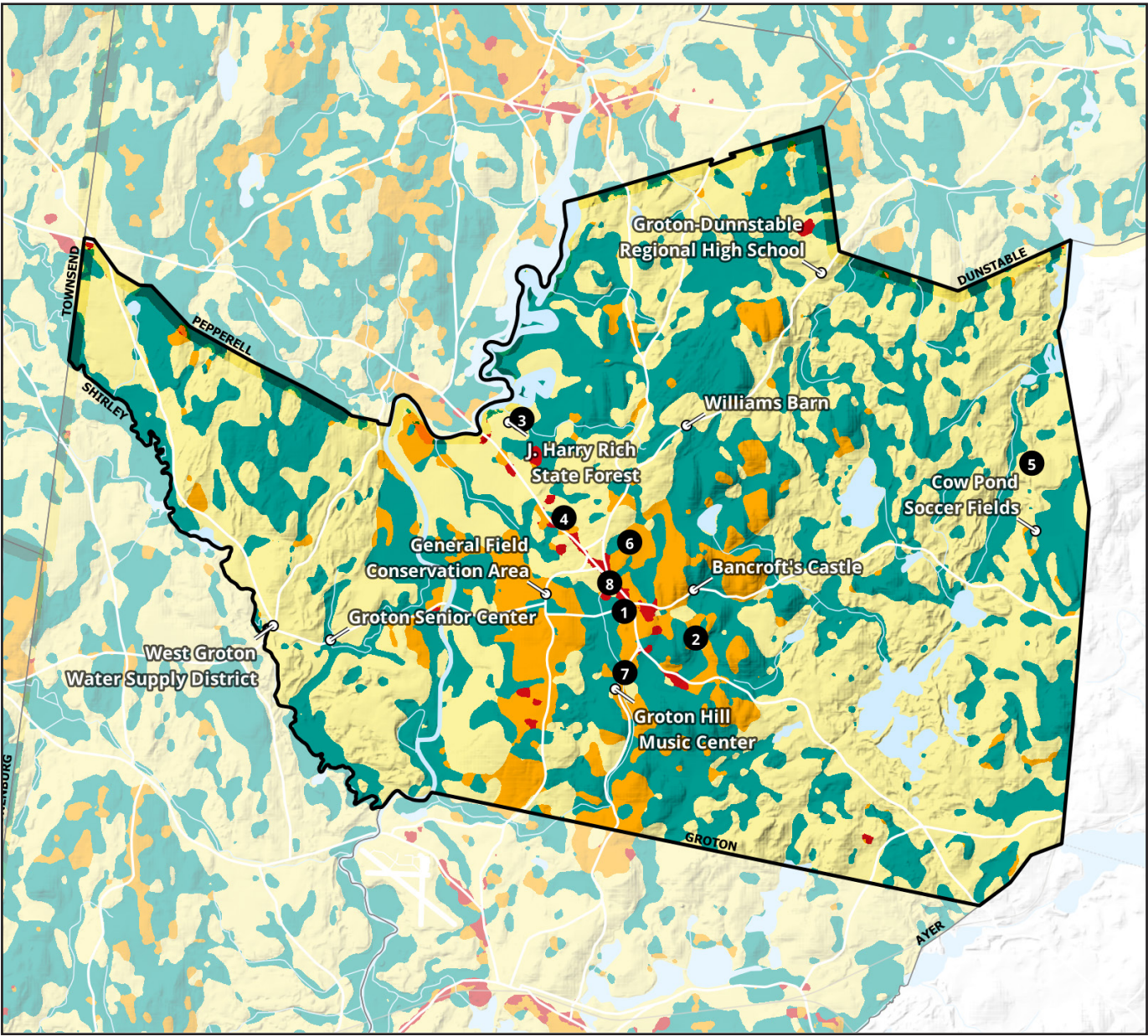
Priority Actions for Protecting/Enhancing Soil Health in Groton

Better management of turf, lawns, gardens, and farms.

Example Nature-based Solutions:

- Education and outreach to key landowners and farmers about smart soil practices
- Pocket forests to transform biodiversity
- Planting and earthworks to restore connectivity and hydrology
- Front yard pollinator meadows
- Dual use solar
- Planning and zoning to preserve and enhance ecosystem function

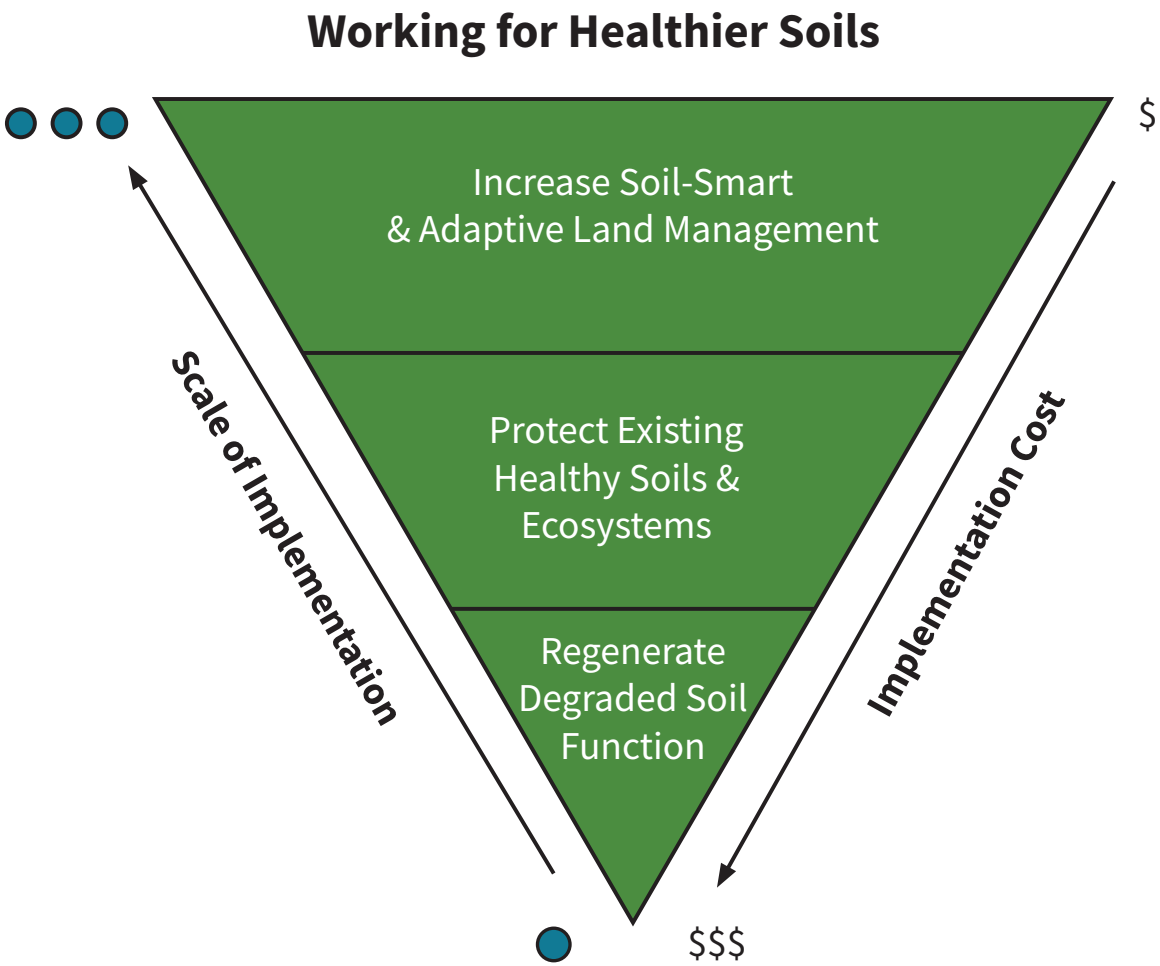
Soil Functions for Resilience



	Groton
High Performance Soils & High Carbon Soils	8,314 ac (38.5%)
Average Function Soils	11,315 ac (52.3%)
Degraded Soils with High Regeneration Potential	1,849 ac (8.6%)
Highly Degraded Soils	138 ac (0.6%)

- Landmarks
- 1 Sites Considered for Nature-based Solutions

Actions for Better Soil Health



Strategies for protecting and improving soil health at the community-wide and regional scale fall on a spectrum with a generally inverse relationship of scale to cost of implementation.

INCREASED PROTECTION AND CLIMATE-FORWARD MANAGEMENT OF WETLANDS AND FORESTS

Wetlands and forests not only provide essential ecosystem functions like nutrient storage, stormwater infiltration, and habitat diversity, but are critical to global and local carbon budgets. Together, wetlands and forests are the largest pool of stored soil carbon on land.

In Ashburnham, Fitchburg, Leominster, Pepperell, and Groton, forested and wetland soils contain approximately 7.24 million tons of soil organic carbon. To help these important ecosystems continue their carbon capturing activities and to prevent loss of the carbon they’ve already stored, it is essential to protect them from land conversion and degradation and to improve management practices.

The following sections describe the issues, opportunities, and pathways for action more specifically.

WETLANDS

The over 10,000 acres of wetland soils in the five project communities contain almost 1.7 million metric tons of soil carbon. The saturated soils of wetlands inhibit decomposition and allow extraordinarily high levels of carbon-rich organic matter to accumulate over centuries. As a result, wetland soils account for nearly one-third of the world's total soil organic carbon pool to 1 meter depth.

In these communities, like most of Massachusetts, humans have converted the majority of pre-colonial wetland acres to other uses. Historically, most of these wetlands were "reclaimed" for agriculture, draining large areas at one time. More recently the majority of wetland losses have occurred from the development of residential and commercial spaces. While the Wetlands Protection Act restricts disturbance and requires replication, whenever an existing wetland is drained or otherwise disturbed, much of this carbon is rapidly lost to the atmosphere. Wetland replication, which attempts to convert upland soils to hydric conditions, fails at a rate of more than 70%. Replications, even when successful, contribute to increased greenhouse gas emissions for decades to centuries as their soils develop the characteristics of wetlands. Emissions from both disturbance and replication accelerate climate change, and the loss of soil carbon from disturbed wetlands diminishes the unique water storage and filtration capacities of these soils. In this way, draining or degrading wetlands increases flood risk and lowers surface water quality, both of which threaten soil health through erosion and contamination.

However, protecting and restoring wetland ecosystems can have an outsized positive impact on soil health and climate resilience, locally and globally.

One step in protecting wetlands from development is to update the municipalities' Wetland Protection Bylaw to directly address soils and increase buffers (See MACC's newly revised model bylaw found at: https://www.maccweb.org/resource/collection/B9CAD8F9-C851-4760-91CF-B162347D22CF/MACC_Model_Bylaw.doc). Additionally, a Transfer of Development Rights Bylaw and Creative Development Bylaw could reduce wetland soils conversions by allowing for more density. Draft bylaws are included in Appendix 1.

Wetland restoration, also known as re-wetting, has been identified by many bodies, including World Economic Forum and the Massachusetts Executive Office of Energy and Environmental Affairs (EOEEA), as one of the most effective ways to mitigate climate disruptions and biodiversity collapse. Re-wetting is the practice of restoring wetland hydrology to historically drained soils and managing them for a diversity of native species. Wetland restoration, as compared to replications, has a high success rate for rapidly reestablishing wetland functions, including carbon sequestration.

Funding for wetland conservation and restoration is available from several sources, depending on property ownership, conservation status, and current land use. For town and regional partnerships, funding may be available through a number of grants offered by The National Fish and Wildlife Foundation, Massachusetts DEP, and from the MVP Program. Farmers and some other landowners may be eligible for funding through various NRCS programs, including the Conservation Innovation Grant and the Environmental Quality Incentive Program.

In addition to seeking funds for municipal and regional projects, educating farmers, educational institutions, and large commercial site managers about the advantages of wetland conservation and re-wetting should also be a priority for future climate resiliency projects.



Bemis tract near town wells. Pepperell, MA. Photo Credit: Ralph Baker

FORESTS

According to the Woodwell Climate Research Center, in the United States, forests and trees “offset 13 percent of emissions from other sectors annually” through annual sequestration. More than 50% of all carbon stored in forests is found in soils. Maintaining and/or increasing these existing stores of carbon requires the dynamics of a healthy and robust canopy of trees and shrubs.

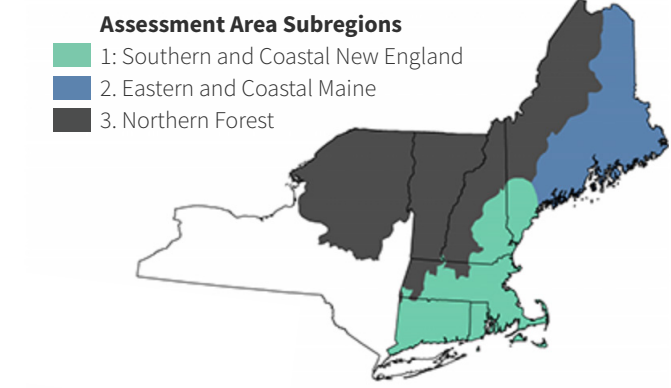
Recent introductions of pests and diseases, combined with increased stressors of heat, drought, and late winter warming, have led to significant declines in the health of several key forest tree species and other challenges to forest health. According to climate projections these trends are likely to intensify.

These challenges require new approaches and management practices in order to protect forest soils, their functions, and their stores of carbon. Applying climate-smart forest management practices and actively helping forests adapt to climate change, in conjunction with increased forest conservation and reforestation efforts, will be necessary to preserve forest function.

Climate-smart practices include proactive tree planting, reforestation in both urban and rural settings, planting trees in existing forests to increase stocking and preserve forest structure, managing invasive species, and protecting seedlings from deer browse. Many of these approaches and practices will be new to New England foresters and forest owners. However, there are a number of excellent resources available to describe emerging issues and to support this important work.

Threats:

Researchers from the Northern Institute for Applied Climate Science (NIACS) have conducted assessments of tree species and climate change vulnerability in three forest subregions of New England. According to the NIACS assessment, the five project municipalities are located on the edge of the Southern and Coastal New England Forest and Northern Forest Types.



NIACS Forest Area Subregions. source: NIACS

In addition to species like Eastern Hemlock and White Ash that are known to be under great stress, NIACS's analysis suggests that common species in the communities' forests like American basswood, balsam poplar, black ash, black walnut, eastern white pine, northern pin oak, and paper birch are among the species likely to suffer as climate change progresses. Actively planting species that show good capability to adapt, like shagbark hickory and chestnut oak, in areas dominated by poor-capability species will be necessary to preserve a diverse forest canopy in the coming decades.

The full vulnerability assessment can be found here: https://www.fs.fed.us/nrs/pubs/gtr/gtr_nrs173.pdf.

Species found by the NIACS assessment to have good capability to cope or persist with climate change in the Southern and Coast New England region are:

- American beech
- Post oak
- American holly
- Red maple
- Black cherry
- Sassafras
- Black oak
- Scarlet oak
- Blackgum
- Shagbark hickory
- Chestnut oak
- Sugar maple
- Eastern red cedar
- Sweetgum
- Mockernut hickory
- White oak
- Northern red oak
- Yellow-poplar
- Tulip poplar

A complete list of vulnerable and capable tree species is found in Appendix 3 (page 77).

Guides:

There are several excellent guides for those interested in understanding how forests can be protected and managed for increased climate resiliency and to mitigate the worst effects of climate change. These include New England Forestry Foundation's Exemplary Forestry Program, the Healthy Forests for Our Future Management Guide from the Nature Conservancy and the Northern Institute for Applied Climate Science, and Massachusetts Forestry Best Management Practices Manual. Each of these describes management practices designed to increase carbon storage, improve wildlife habitat and biodiversity, and grow healthier trees in the forests of New England.

Exemplary Forestry is a forest management approach created by New England Forestry Foundation (NEFF) that prioritizes forests' long-term health and outlines the highest standards of sustainability currently available to the region's forest owners for three key goals: enhancing the role forests can play to mitigate climate change, and growing and harvesting more sustainably produced wood.

Similarly, the Forest Resilience Program trains professional foresters in specific climate-smart forestry practices that have been verified to increase carbon storage and reduce future carbon emissions by increasing forest resilience. Hiring professionals trained in these practices can help forest managers implement practices that maintain forest canopy integrity, resulting in the preservation of forest soil health.

Funding:

Several Natural Resources Conservation Service practices may support reforestation efforts, including: tree/shrub establishment, riparian forest buffers, tree/shrub site preparation, and planting for high carbon sequestration rate.

Recommendations:

- Update existing forest stewardship plans to integrate soil and climate informed forestry principles and practices on all municipal owned or managed lands. Encourage citizens to do the same.
- Encourage reforestation of vulnerable soils including riparian floodplains + slopes greater than 15%
- Establish a Forest Protection Zone to discourage development on upland forest soils. Model language for an FPZ is provided in Appendix 1 (page 67) of this document.
- Adopt updated Wetlands Protection Bylaw included in Appendix 1 as forested wetlands represent the majority of disturbed wetland acres in Massachusetts.



Fall Brook behind Meadowbrook Acres. Leominster, MA. Photo Credit: Ralph Baker

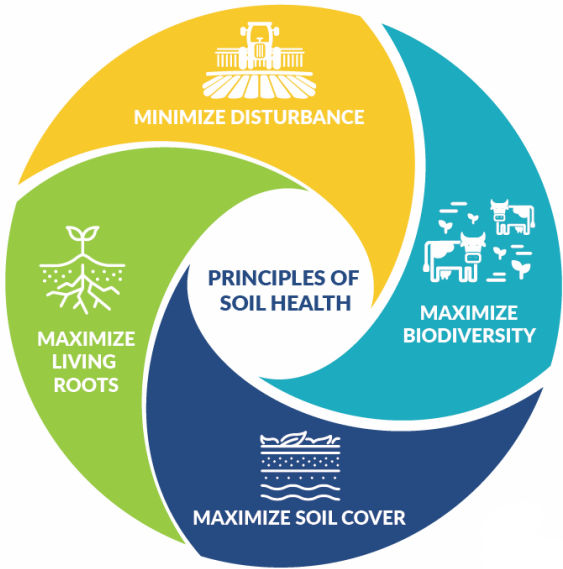
BETTER MANAGEMENT OF TURF, LAWNS, GARDENS, AND FARMS FOR SOIL HEALTH.

By increasing soil organic matter on all turf, landscaped, and agricultural land in the five project municipalities by 1%, approximately 113.5 million additional gallons of water can be absorbed, stored, and made available to plants. This not only means land managers will have to irrigate less during droughts, but that these lands can act as a sponge to absorb stormwater, potentially reducing the destructive effects of flooding.

More than 11,500 acres of soil in the five communities are managed as turf, lawn, gardens, or agriculture. Achieving greater soil health on these soils will require the land managers to make many changes both big and small. These changes can include the reduction or elimination of chemicals shown to be detrimental to soil health, such as pesticides, herbicides, and artificial fertilizers. While each property will require different treatments, the NRCS provides four research-based principles of soil health to guide decision making:

- 1. **Maximize Presence of Living Roots:** Healthy soil is dependent upon how well the soil food web is fed. Recently dead plant roots, crop residues, and soil organic matter all feed the many and varied members of the soil food web, but living roots deliver the lion's share of sugar to the bacteria and fungi that form its foundation. Land managers can maximize living roots by maintaining living plants across the landscape for as much of the year as possible. On farms, for example, multi-species cover crops, crop rotations, and the integration of perennials, shrubs, and trees into cropping systems are practical ways to keep more living roots growing in the soil.

- 2. **Minimize Disturbance:** Physical soil disturbance, such as tillage, results in bare and/or compacted soil that is destructive to soil microbes. Misapplication of landscape inputs can disrupt the symbiotic relationships between fungi, other microorganisms, and plant roots. In pasture lands, overgrazing, a form of biological disturbance, reduces root mass, increases runoff, and increases soil temperature. All forms of soil disturbance diminish habitat for soil microbes and result in a diminished soil food web.
- 3. **Maximize Soil Cover:** Soil cover conserves moisture, reduces temperature, intercepts raindrops (reducing their destructive impact), suppresses weed growth, and provides habitat for members of the soil food web that spend at least some of their time above ground. This is true regardless of land use. Keeping the soil covered while allowing plant residues to decompose (so their nutrients can be cycled back into the soil) can be a bit of a balancing act.
- 4. **Maximize Biodiversity:** A diversity of plant carbohydrates is required to support the diversity of soil microorganisms in the soil. In order to achieve a high level of diversity, a variety of plants must be grown. The key to improving soil health is ensuring that food and energy chains and webs consist of several types of plants or animals, not just one or two.



Principles of Soil Health
source: NRCS

TURF AND LAWNS

Recreational and ornamental landscapes, especially turf and lawns, are the most heavily managed soils outside of agriculture. Playing fields and many lawns receive regular irrigation, fertilizer, and other soil amendments that increase soil cover but have varying effects on soil health and water quality. A review of the scientific literature regarding carbon sequestration in turf shows that under best management practices, residential lawns, golf courses, and academic campuses have an impressive potential to sequester more carbon, improve soil structure, and store more water (Kumar et al, 2016, Selhorst & Lal, 2012, Qian and Follett, 2009). However, over-fertilization, short mowing, and removal of clippings and other yard ‘wastes’ is well-known to diminish soil health and contribute to surface water pollution.

Encouraging campus managers, home owners, and public works employees to implement soil-smart practices on the 6,000 acres in turf and lawn is a powerful way to ensure these recreational and aesthetic grasslands contribute to soil health and municipal long term climate goals.

Guidelines for managing existing turf and lawns

- **Get to know the soil.**
 - Observe soil texture. Soil texture affects the water and nutrient dynamics of soil. Sandy soils drain quickly and hold fewer nutrients than clay soils. Dig a hole and notice if the soil is sandy, heavy with clay, or somewhere in between.
 - Send soils in for testing to determine if any amendments or fertilizer are required.
 - UMass Soil and Plant Nutrient Testing Laboratory offers a variety of tests including the Routine Soil Analysis for Turf, Ornamentals, and Landscaping that can guide management. Testing is easy, inexpensive at \$20/sample, and the recommendations provided with results are excellent. More information can be found at <https://ag.umass.edu/services/soil-plant-nutrient-testing-laboratory/ordering-information-forms>
 - Tracking Organic Matter. Increasing soil organic matter (SOM) to between 3-8% dramatically increases water holding capacity, aeration, nutrient availability, and plant health. Because soil organic matter is 58% carbon, increasing SOM pulls more carbon out of the atmosphere. Following the recommendations below can help raise SOM
- **Raise mower height to encourage deeper rooting.**
 - Experts like UMass Cooperative Extension suggest mowing turf grass at 3 to 4 inches to improve performance of both plants and soil.

- **Feed the soil, not just the grass.**
 - Leave grass clippings on the lawn. Removing grass clippings is akin to slowly mining minerals and fertility from the soil, whereas leaving grass clippings on the lawn feeds soil organisms, which in turn create good soil structure. This practice is made easier with a mulching mower and may reduce the need for fertilizer and irrigation.
 - Fertilizer: Test, don't guess.
 - Follow recommendations from soil tests.
 - Add mineral amendments first. Some areas are low in minerals like magnesium or calcium. These are the building blocks of fertility and addressing these imbalances will help soil and plant health in the long term.
 - Use slow-release fertilizers for N-P-K, not water soluble types.
 - Pay attention to the size of the lawn and properly calibrate application equipment.
 - Time it right:
 - Soil and grasses are most able to make use of fertilizers and mineral amendments in the spring and fall. Memorial Day and Labor Day can serve as helpful reminders.
 - Avoid fertilizing when heavy rains are forecast within a few days.
- **Aerate lawns to allow plants to breathe and spread.**
- **Overseed with the ‘right’ mix.**
 - Overseeding in the spring or fall with a mix of grasses and other plants suited to the climate and use can add beneficial diversity and ‘patch’ bare spots. For lower use areas, consider species like red fescue that thrive with less frequent or no mowing. Clover fixes nitrogen and can ‘share’ that nutrient with other species helping more heavily used grass recover.
- **Plant a tree.**
 - Research shows that grasslands that include woody plants have approximately 20% higher SOC stocks compared with grass alone. However, trees with very dense canopies or that are densely planted can shade out grasses. The best trees to add to a lawn or around athletic turf will cast a lighter shade like hybrid elms or honey locust.

Education and Outreach Efforts:

To improve soil health on turf and lawns throughout the Nashua River watershed, it is recommended that the municipalities establish and expand programs to increase awareness and knowledge of soil health in turf, lawns, and other ornamental landscapes. Essential actions include:

1. Develop specific materials for large land managers and residential lawn owners.
2. Provide healthy soils training for professional land managers, turf professionals, and landscapers, especially municipal/college employees.
3. Encourage lawn conversion to native habitats through meadow establishment, transition to shrublands, and reforestation.
4. Seek and allocate funding for equipment change-over to allow for BMPs including electric mowers with higher decks and mulching capabilities.
5. Collect and track soils data against land management practices over time:
 - a. Establish an annual testing program to track changes in soil organic matter on representative sites for each Soil Carbon Conservation Class.
 - b. Build on Demonstration Sites sampled during this project.

Equipment Change Over to Allow BMPs

Improving soil health practices on turf and lawn landscapes requires equipment with specific features. It is recommended that each community establish a local commitment: all new municipal mowing equipment shall have mulching capabilities and be able to raise their decks to 4” or more.

Furthermore, considering electric powered equipment can have human health and air quality benefits. Some manufactures of commercial grade electric mowers include:

- [Gravely Electric Mowers](#)
- [Mean Green Electric Mowers](#)
- [Greenworks Electric Mowers](#)

Residents may also be encouraged to take advantage if existing rebates for lawn equipment through the MassSave program:

[MassSave rebates on electric lawn equipment](#)

Inspiring precedent programs that support equipment upgrades are Utah’s [Renew Choice](#), and California’s [Electric Lawn Mower Rebate](#) programs. While these are sponsored by state governments, each community could considering seeking funding to establish a local program.

Data Collection and Tracking

Collection, tracking, and analysis of soil data over time will provide necessary feedback on the effectiveness of future efforts at improving and conserving soil health.

Recommendations for data collection and tracking:

- Provide low-cost or no-cost soil testing and amendment recommendations for land owners/managers who pledge to the program for three years. Both the UMass and Cornell Soil Labs provide excellent tests with clear recommendations.
- Conduct tests annually for the three years and include soil organic matter (SOM), bulk density, and water holding capacity.
- Set up a data aggregation and tracking system that catalogs change over time in SOM, bulk density, and water holding capacity and indexes this to management practices.
- Collect and track data as a municipal led, volunteer-run program or in collaboration with high school science classes.
- Partner with Conservation Districts as an official pilot program.

CROP LANDS

3,680 acres in the five project communities are agricultural lands. These are actively and highly managed landscapes and so may have a high potential for regenerative intervention. These general recommendations from the NRCS can be applied to all agricultural lands of Ashburnham, Fitchburg, Leominster, Pepperell, and Groton.

1. **Reduced tillage:** A variety of lower till systems exist, which require some specialized equipment and substantial knowledge. Systems include strip tillage; conventional no-till which relies on an herbicide to kill cover crop; and organic no-till with uses precisely timed rolling and crimping to kill the cover.



Comparing soil under till (left) and no-till (right) practices. source: Dale Strickler, Civil Eats

2. **Cover crops:** Supporting farmers to plant cover crops at the right time of year either by overseeding a cash crop or earlier harvests would have good effect. Diversifying cover crop selection both over time and in field at any time is also likely to provide benefits.
3. **Increase application of organic matter:** Compost, mulch, or cover cropping can help rebuild carbon stocks and may be necessary to allow reductions in agricultural chemicals.
4. **Experiment with remineralization:** Rock dusts and mineral amendments can provide a wide array of micro and macro nutrients to crops and cover crops. Agricultural lime has long been applied to supply calcium and adjust soil pH. Expanding the use of mineral amendments like greensand, azomite, and rock phosphate can provide better soil nutrition while limiting soil and water quality impacts of soluble fertilizers. Recent research also shows that basalt dust can increase the carbon sequestration rate of croplands and forests.

HAY LANDS

Manage Against Compaction

It is impossible to avoid compaction when making hay with heavy modern equipment. Periodic ripping (subsoiling) and punching (aeration) are methods used to break up compaction and improve infiltration, but agronomic research has not convincingly demonstrated the benefit of these practices—and they are remedial actions that won’t prevent compaction from happening again. Ripping tends to produce an uneven soil surface that results in a need for disking; these added field passes cost time and fuel and may also add to compaction at the same time.

Recommended methods for reducing compaction in the field are summarized below:

Higher Cuttings

A common refrain among working grasslands specialists is that “below ground mirrors above ground,” meaning the height of the cut influences root mass and root depth. Cut too low, and it recovers more slowly—and cut too low too often, the root mass and root depth will decline. This condition, combined with vehicle traffic on fields, can lead to compaction issues.

Higher cutting, on the other hand, leads to stronger, deeper roots that can push through and loosen compaction. The University of Maryland extension recommends leaving 2-3 inches for alfalfa and 4 inches for cool season grasses, and the University of Ohio Extension specialists recommend cutting even higher for warm season grasses.

Professor Richard Kersbergen of the University of Maine also advises a 4 inch cutting height. While overall yield may lessen, the feed quality of the harvested hay will be significantly better. This approach is preferable even to skipping a cut of hay each year on compacted fields (except for especially wet years).

Rotationally Grazed Hayfields

Hay production removes biomass from the field, which can gradually reduce soil health over time. Rotational grazing of hayfields as often as every other year (as field position, land resources, labor, and fencing resources allow) builds back soil health. The cycling of nutrients provided by manure, urine, and trampling stimulate grass health and root growth.

According to Professor Kersbergen, pasture health can also benefit from a full season hay rotation. Since hoof traffic and haying have different impacts on soil health, simply changing the management practice for a full season can alleviate areas of compaction and allow grassland revitalization.

Cover Crop Interseeding

Another practice that may support soil health, but about which current research is scarce, is the interseeding of cover crops into hayfields and pastures. Some producers and agronomic advisors advocate seeding certain cover crops into perennial grasslands (especially seeding warm-season cover crops into cool season pastures to overcome high summer growth slumps).

While the research shows limited biomass gains from this practice, one promising area is the use of tillage radish for nutrient scavenging and compaction mitigation. A SARE farmer research project (Report: Tillage Radish Trials for Reducing Compaction on Pastures, Apple Creek Farm) found that adding tillage radish to established but compacted pastures improved infiltration rates and nutrient cycling—and provided an additional palatable summer forage for livestock. Radish is very attractive to wildlife, so it may suffer from deer and rabbit pressure, but trialing it would be a good way to determine whether this is a viable approach for compaction moving forward. Tillage radishes are likely to survive late haying with higher cutting.

Organic Matter

Regular removal of biomass from a hayfield depletes the O horizon, compromising the soil ‘armor’— a biologically active zone where fungi, bacteria, and soil organisms proliferate, protecting against temperature and precipitation extremes.

All methods mentioned above can help retain more biomass in the field, but adding organic matter in the form of compost, composted manure, or even chopped leaves and partially decomposed wood chips, can all reintroduce biomass. The microbiological diversity, organic residues, and nutrients associated with these organic inputs kickstarts soil health, which can have the downstream effect of increasing root vitality and mitigating compaction.

PASTURE LANDS

Reduce Paddock Size + Increase Rotation

Intensive rotational grazing plans are shown to improve soil health and pasture productivity while decreasing weed pressure on pastures. These grazing systems require a higher level of pasture management, and an investment in fencing, water, and labor for livestock operations. Reducing paddock size and increasing the frequency of rotations encourages more even grazing, prevents overgrazing, and ensures a better distribution of fertility-boosting animal waste.

In general, large paddocks should be subdivided with permanent or temporary fencing, and herds should be moved multiple times per week. Close monitoring is needed to ensure pastures are not grazed below 4 inches to allow for proper regrowth.

The specific stocking rate, paddock size, and length of grazing period will depend on the forage type, growing conditions, and more, so these should be specific to the pasture and time of year. Changes in grazing plans, including rotation duration and stocking rates, must be made in real time by the manager to ensure pasture and soil health.

See guides from the USDA-NRCS to assist in the development of a rotational grazing plan. Additional recommended grazing resources include:

Grazing and Pasture Management for Cattle (*UMN Extension*) and Management Intensive Grazing (*UGA Extension*)

SUPPORTING FARMER-LED SOIL HEALTH IMPROVEMENTS

Lower-till or no-till crop production, more intensive pasture management, and hay production that builds organic matter represent the most significant and lowest-barrier improvements for farmland management in Massachusetts. For these actions, the municipalities, in partnership with the local Soil Conservation District, can assist farmers in accessing funding for technical assistance, training, equipment purchases, and other implementation needs from the Natural Resource Conservation Service and organizations, like UMass Extension, American Farmland Trust, and Northeast Organic Farming Association.

Protecting flood prone areas and restoring wetlands that have been previously modified for agricultural use has the potential to restore thousands of tons of carbon to agriculturally managed soils and protect farmland from mass erosion events like those seen around Massachusetts in Hurricanes Irene and Sandy. However, these actions, which include the establishment of riparian forests, perennial crops, or grassed conservation stripes, require farmers to relinquish hard-won productive acres.

A variety of approaches can encourage and compensate farmers that undertake these significant changes. The first is ensuring that farmers are aware of existing funding sources such as the NRCS Environmental Quality Incentives Program and Conservation Innovation Grants. A second approach involves seeking funding for watershed restoration projects that include riparian and wetland enhancements. For example, the U.S. Fish and Wildlife Foundation manages the New England Forests and Rivers Fund which seeks to improve water and habitat quality in the streams and rivers of the region. Each year the program awards competitive grants ranging from \$50,000

to \$200,000 each. By partnering with local watershed conservation organizations, land trusts, consultants, and restoration organizations such as the Nashua River Watershed Association, MassAudubon, The Nature Conservancy, and Trout Unlimited, municipal partners could seek such funding to restore historically drained wetland or similar habitats located on farms. Lastly, several statewide efforts are underway in Massachusetts that are likely to provide funding for many innovative soil management and regeneration efforts. The Resilient Lands Initiative and the Healthy Soils Action Plan, both released in 2023, identify the reforestation of riparian areas as priority actions.

REGENERATE OR REPLICATE LOST SOIL FUNCTION IN HIGHLY DEGRADED URBANIZED LANDSCAPES

SOIL-SMART CONSTRUCTION AND DEVELOPMENT PATTERNS & PRACTICES

The construction processes associated with residential and commercial development typically removes all vegetation, strips much of the topsoil, and relies on extensive grading. This permanently alters the drainage dynamics of the native soil by simplifying topography and compacting subsoils. The development process is often ‘completed’ with the addition of a thin layer of ‘top-soil’ or ‘loam’ directly on top of a highly compacted mineral soil. The resulting soil conditions limit the depth to which plant roots can travel, compromising water infiltration, storage capacity, and the depth of carbon sequestration. These conditions can limit landscape performance for decades or longer and require higher inputs of fertilizer, water, and other labor to sustain a functional landscape.

However, thoughtful development can transform these impacts. First, by focusing new development on previously developed soils (rather than on farms, forests, or wetlands), new construction activities can actually improve soil health through remediation or renovation.

Where development on current green space is unavoidable, implement requirements for achieving high soil performance following construction.

Soil best practices during construction:

- Retain and protect native topsoil & vegetation where practical.
- Restore disturbed soils, to healthy soil function:
 - » Stockpile & reuse good quality site soil, or
 - » Increase organic matter content in top 8” of soil to 3-8% by:
 - o Tilling 2-3" of compost into site soils, or
 - o Bringing in 8" of compost-amended topsoil.
 - » Loosen compacted subsoil by ripping or airspading to 12" depth.
 - » Mulch landscape beds after planting.
 - » Protect restored soils from erosion or re-compaction by heavy equipment.

GREEN INFRASTRUCTURE

In areas where soil disturbance and construction have resulted in impervious and compacted soil conditions, a variety of green infrastructure solutions may be implemented to replace losses in soil function.

In planting strips, lawns, and other greenspaces, decompaction with the addition of organic matter, targeted mineral amendments, and biological inoculants can catalyze the establishment of healthy soil biology, carbon dynamics, and nutrient flows that support plant growth.

Stormwater infiltration and filtration can be improved by installing rain gardens, bioswales, and other similar features. Stormwater interception, carbon sequestration, and water holding capacity can be increased by adding canopy trees to lawn areas, verge zones, and parking lots.

RESTORATION

Restoration efforts such as daylighting streams, dechannelization, and restoring riparian corridors and wetlands can significantly enhance water quality and foster greater species diversity. Implementing targeted solutions like establishing pollinator corridors, creating pocket forests, and other strategies that promote habitat connectivity further amplify these benefits.

TRANSFER OF DEVELOPMENT RIGHTS

This TDR bylaw would establish two zones: a Sending Zone and a Receiving Zone. It would establish a Special Permit process allowing the transfer of development rights from the Sending Zone to the Receiving Zone. The Sending Zone would comprise prime agricultural lands and upland forest areas. The Receiving Zone would comprise existing village centers, commercial and industrial districts and other areas of degraded soils.

The bylaw would direct development toward previously developed and degraded soils (*Receiving Zones*) by offering incentives (i.e. increased density, lot coverage, building height, or reduced parking or setback, or options for mixed use). In return for these incentives, an applicant would purchase and preserve the development rights for a parcel(s) in the Sending Zone, or make a financial contribution to a municipal open space fund.

The model TDR bylaw in the appendix would also establish a Mixed Use Village Center receiving zone with regulations and incentives to promote more compact development with a mix of residential and commercial uses in the same building(s) in the town center.

CREATIVE DEVELOPMENT

“Creative Development” is an updated version of regulations for residential cluster development with required open space protection, that can effectively reduce the impacts of urban sprawl and protect blocks of forested or farmed soils. A great precedent of this strategy in the Nashua River Watershed is the innovative residential development Emerson Green in Devens.

Aligning Land Use Regulations with Soil Health

This section describes regulatory strategies that Ashburnham, Framingham, Leominster, Pepperell, and Groton can employ to preserve, protect, and better manage its soils.

As outlined earlier in this report, the highest priority soils for preservation, based on soil organic carbon stocks, are in order of importance:

- 1) Wetlands
- 2) Forests
- 3) Treed Areas Outside of Forests
- 4) Shrublands or Grasslands
- 5) Agricultural Lands
- 6) Turf & Landscaped Areas

The strategies identified in the table on the following page are targeted toward preserving soil health in these land covers, while directing new development to areas with more degraded soils.

(See Appendix 1 for full text of model bylaws):

Table 3. Healthy Soils Strategies

ISSUE	STRATEGY	LEAD ENTITY
Protecting wetlands soils	Local wetlands bylaw with improvements to create larger buffers*	Conservation Commission
Protecting upland forest soils	Forest uplands overlay district*	Planning Board
	Tree protection bylaw (see Significant Trees bylaw)*	Planning Board
	Broader use of the Community Preservation Act (CPA) to preserve open space	Community Preservation Committee
	Collaboration with land trusts to preserve key parcels	Open Space Committee
	Open space grants to preserve key parcels	Open Space Committee
Protecting agricultural soils	Creative Development bylaw to promote cluster development with open space protection*	Planning Board
	Transfer of Development Rights bylaw *	Planning Board
	Broader use of CPA to promote APRs	Community Preservation Committee
	Collaboration with land trusts to preserve key parcels	Community Preservation Committee
Construction impacts to soils	Open space grants to preserve key parcels	Open Space Committee
	Post construction soil performance standards*	Planning Board
Protect and re-forest river corridors, riparian areas	River protection overlay zoning	Planning Board
	Incentives for farmers to re-forest riparian corridors	Healthy Soils funds, via Conservation Districts
Minimize solar development impacts	Increase incentives for solar projects on rooftops, parking lots, roadsides, and brownfields and other already altered sites and to reduce or eliminate incentives for important natural and working lands.	Planning Board
	Incentivize multi-use solar development on agricultural lands when it has clear benefits for farm viability and soil health. Solar grazing and solar cropping are examples of beneficial dual use.	Planning Board

*Note: See model bylaw for these strategies in Appendix 1.

Below are descriptions of recommended regulatory actions for the five project communities. Relevant sections from earlier pages have been included here.

Transfer of Development Rights

This TDR bylaw would establish two zones: a Sending Zone and a Receiving Zone. It would establish a Special Permit process allowing the transfer of development rights from the Sending Zone to the Receiving Zone. The Sending Zone would comprise prime agricultural lands and upland forest areas. The Receiving Zone would comprise existing village centers, commercial and industrial districts and other areas of degraded soils.

The bylaw would direct development toward previously developed and degraded soils (*Receiving Zones*) by offering incentives (i.e. increased density, lot coverage, building height, or reduced parking or setback, or options for mixed use). In return for these incentives, an applicant would purchase and preserve the development rights for a parcel(s) in the Sending Zone, or make a financial contribution to a municipal open space fund.

The model TDR bylaw in the appendix would also establish a Mixed Use Village Center receiving zone with regulations and incentives to promote more compact development with a mix of residential and commercial uses in the same building(s) in the town center.

Post Construction Soil Performance Standards

Naturally occurring, undisturbed soil and vegetation provide important stormwater functions including water infiltration; nutrient and pollutant absorption; sediment and pollutant biofiltration; water interflow storage and transmission; and pollutant decomposition. These functions are largely lost when development removes native soil and vegetation and replaces it with minimal topsoil and sod.

Post Construction Soil Performance Standards would apply to all disturbed areas within the limits of the site which are not covered by an impervious surface, incorporated into a structural stormwater treatment practice, or engineered as structural fill once development is complete.

These standards would require:

- Retention, in an undisturbed state, of the duff layer and native topsoil to the maximum extent practicable;
- Limiting total site disturbance;
- Mitigating soil compaction;
- For disturbed areas, post construction soil quality that meets standards for topsoil depth and minimum organic matter;
- The soil quality requirements shall be met by using one

or a combination of the following methods:

- » Option 1: Leave undisturbed native vegetation and soil, and protect from compaction during construction.
- » Option 2: Amend existing site topsoil or subsoil in place.
- » Option 3: Remove and stockpile existing topsoil during grading.
- » Option 4: Import topsoil mix, or other materials for mixing, including compost, of sufficient organic content and depth.
- Planting to replace vegetation removed during construction.

Upland Forest Protection Overlay District

Some of the most valuable and healthy soils in the Nashua River watershed communities are in the forested uplands. An Upland Forest Protection Overlay District for forested areas above a certain elevation (i.e. 400 feet) would establish regulations to protect these forest soils via:

- Restrictions on clear cutting of forests, with selective forest cutting allowed in conformance with a Forest Cutting Plan approved in accordance with the Mass. Forest Cutting Practices Act;
- Site plan review for all new development, except enlargement of pre-existing uses;
- Additional site plan standards within the overlay district for:
 - » Minimizing tree removal during construction;
 - » Erosion prevention and on-site stormwater retention;
 - » Limitations on grading;
 - » Designated building envelopes;
- Limits on driveway length.
- Reduced densities, and incentives for cluster development with protected open space.

Expanded Wetland and Water Resource Buffers

The soils with the highest level of carbon sequestration are soils in and around wetland areas. Protecting these soils is particularly important.

The Massachusetts Wetlands Protection Act establishes that a buffer zone is the area of land within 100 feet of coastal banks, inland banks, freshwater wetlands, coastal wetlands, tidal flats, beaches, dunes, marshes, and swamps. Work (activity) in a buffer zone could have an impact on the nearby wetland, depending on the type and location of the work and the wetland. Thus, many activities done in a buffer zone (other than minor activities set forth in the regulations and exempt activities) are subject to regulation under

the Act and require prior approval by the conservation commission. A conservation commission may impose conditions or limits on activity done in a buffer zone so that the nearby wetland is protected.

In addition to the Massachusetts Wetlands Protection Act, a majority of the cities and towns in Massachusetts have their own wetlands ordinances/bylaws that provide more protections to wetlands than does the state law. The state and local wetlands laws are administered together by the local conservation commission. Work must meet the stricter of the state and local requirements. Some cities and towns also have wetlands protection requirements in their zoning ordinances/bylaws.

Many towns in Massachusetts have adopted local Wetlands Protection bylaws to expand the wetlands buffer zone. Some example include:

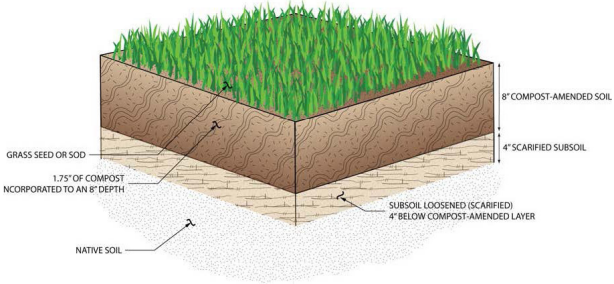
- Brookline — 150-ft Buffer Zone to all resource areas;
- Blackstone — 150-ft Buffer Zone if in Public Water Supply Catchment Basin;
- Bourne — increased to 200-ft for resource areas within ACEC, the Waters Resource District, or Bournedale Environmental Overlay District;
- Harvard — 200-ft Buffer Zone to rivers, ponds, vernal pools and lakes (smaller 100-ft Buffer Zone to other resource areas);
- Lancaster — extends 200-ft Riverfront Area to intermittent streams, as well as perennial.
- Framingham — 125-ft Buffer Zone to all resources areas jurisdictional to the bylaw, including Isolated Wetlands, Land Subject to Flooding and Riverfront Area.
- Great Barrington — 500-ft Buffer to public or private water supply (lake, pond, river or stream), and 200-ft Buffer to a lake or pond that is a tributary to a water supply is jurisdictional.

Creative Development

“Creative Development” is an updated version of regulations for residential cluster development with required open space protection, that can effectively reduce the impacts of urban sprawl and protect blocks of forested or farmed soils.



Innovative practices like translocating large blocks of soil with their established plants allows for more rapid wetland replication while preserving more of the beneficial soil function when compared with traditional practices. (G.Davies, BSC Group)



In Seattle, Washington, a post-construction soil performance standard requires builders and developers to create deeper soils that can support healthy plants and high stormwater infiltration. (Seattle Department of Construction and Inspections. Tip 531.)

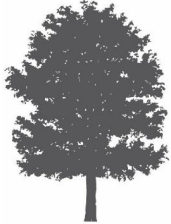
Significant Tree Bylaw

The Significant Tree Bylaw recognizes the unique role large trees have in sequestering and storing carbon. In this bylaw, any tree of 20 inches diameter at breast height (DBH) or larger or any other tree specifically identified as a specimen tree on any Tree Inventory Plan adopted by the Planning Board. This is based on recent research that shows previous assumptions about the carbon storage and sequestration rates of mature verses small trees under-counts the power of large trees. Many forest and conservation professionals had assumed that because

young trees have a faster rate of growth than older, mature trees, that the younger trees stored more carbon per year, and thus cutting the old trees to allow younger ones to grow would be beneficial from a carbon and climate perspective. However, nothing could be further from the truth. While the old giants do grow at a slower rate, their large size means that, for instance, Eastern white pines accumulate the majority (75%) of their total carbon once they are at least 50 years old. Large trees store a much larger amount of carbon than smaller trees.


CARBON ROCK STARS: LARGE, OLDER TREES AND FORESTS

How many oak trees does it take to store 8 tons of carbon?



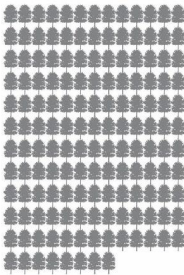
1
Mature Canopy Tree
100' tall x 54" dia

OR



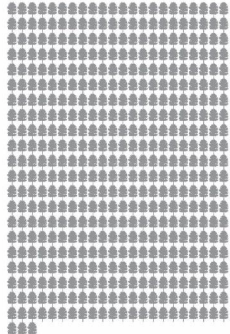
35
Young Canopy Trees
50' tall x 12" dia

OR



151
Typical Street Trees
40' tall x 6" dia

OR



465
New Large Landscape Trees
25' tall x 4" dia

Regenerative DesignGroup

“A large northern red oak measures 14 feet in circumference [54 inches diameter at breast height (dbh)]. Its height is 100 feet. Approximately 50% of this dry weight is carbon, or 7.7 tons. This amount of carbon has a CO₂ equivalency of 28.2 tons. Let’s say we have a 12-inch dbh, 50-foot tall, young northern red oak. It would take 35 young trees to match the carbon of the one large oak. Using a 6-inch dbh, 40-foot tall oak, the number of young trees needed to match the one big tree soars to 151! Finally, let’s drop to a 4-inch DBH and 25-foot height. The number of oaks required skyrockets to 465! It takes 10 or more years to get a young red oak up to this [4-inch dbh] size...Let’s take a young, newly planted tree from nursery stock...its diameter is 1 inch and it is 4.5 feet tall...it would take 61,364 newly planted trees to match the carbon in our one large oak, and they would be three years old!...Assuming each 1-inch diameter seedling controls only 5 ft² of ground space, then the total area needed to hold the seedlings becomes...7.0 acres... The lesson is clear: Save big trees where possible.” - Robert Leverett, Cofounder, Native Tree Society

Source: Leverett R.T. 2021. Carbon Storage in Large vs Small Trees – an Example. Unpublished Text.
Also See: Leverett R.T., Masino S.A, and Moomaw W.R. 2021. Older eastern white pine trees and stands accumulate carbon for many decades and maximize cumulative carbon. *Frontiers in Forests and Global Change* 4: 620450. doi: 10.3389/ffgc.2021.620450

Prepared in 2021 by:

For the Apple Country Natural Climate Solutions Project, a collaboration of the Towns of Bolton, Harvard and the Devens Regional Enterprise Zone.

Funded by the Massachusetts Municipal Vulnerability Preparedness Program.

Timber Harvest Effects on Forest Carbon
FOR 75 YEAR OLD NORTHEASTERN HARDWOOD-DOMINANT FOREST

Forest Age	2024	2030	2050	2100	2150
Total Carbon (mt/ac)	156	95	109	156	186

Carbon Pools:

- LIVE TREES:** Carbon stored in living trees.
- DEAD WOOD:** Carbon stored in dead trees.
- FOREST FLOOR:** Carbon stored in forest floor litter.
- SOIL:** Carbon stored in soil.

Notes:

- Carbon stocks reach lowest levels 5-10 years post-harvest due to continued respiration and lost sequestration capacity.
- 25 years after harvest, total forest carbon is roughly half pre-harvest levels with live tree carbon increasing more rapidly than other pools.
- 75 years post harvest live tree, dead tree, and forest floor carbon return to pre-harvest levels. Soil organic carbon (SOC) may lag due to harvest related soil structure damage.
- 125 years post harvest maturing trees reach middle age. SOC likely to reach saturation while other carbon pools continue to accumulate carbon for decades to centuries.

Data Sources:

- Domke, G. M., Walters, B. F., Nowak, D. J., Smith, J. E., Ogle, S. M., Coulston, J., & Wirth, T. (2020). Greenhouse gas emissions and removals from forest land, woodlands, and urban trees in the United States, 1990-2019: Estimates and quantitative uncertainty for individual states (Resource Update FS-227; p. 5). U.S. Department of Agriculture, Forest Service, Northern Research Station. <https://www.fs.usda.gov/rds/archive/Catalog/RDS-2021-0035>
- Hamburg, S. P., Vadeboncoeur, M. A., Johnson, C. E., & Sanderman, J. (2019). Losses of mineral soil carbon largely offset biomass accumulation 15 years after whole-tree harvest in a northern hardwood forest. *Biogeochemistry*, 144(1), 1–14. <https://doi.org/10.1007/s10533-019-00568-3>
- James, J., & Harrison, R. (2016). The Effect of Harvest on Forest Soil Carbon: A Meta-Analysis. *Forests*, 7(12), Article 12. <https://doi.org/10.3390/f7120308>
- James, J., Page-Dumroese, D., Busse, M., Palik, B., Zhang, J., Eaton, B., Slesak, R., Tirocke, J., & Kwon, H. (2021). Effects of forest harvesting and biomass removal on soil carbon and nitrogen: Two complementary meta-analyses. *Forest Ecology and Management*, 485, 118935. <https://doi.org/10.1016/j.foreco.2021.118935>
- Mayer, M., Baltensweiler, A., James, J., Rigling, A., & Hagedorn, F. (2023). A global synthesis and conceptualization of the magnitude and duration of soil carbon losses in response to forest disturbances. *Global Ecology and Biogeography*, n/a(n/a). <https://doi.org/10.1111/geb.13779>
- Nave, L. E., Vance, E. D., Swanston, C. W., & Curtis, P. S. (2010). Harvest impacts on soil carbon storage in temperate forests. *Forest Ecology and Management*, 259(5), 857–866. <https://doi.org/10.1016/j.foreco.2009.12.009>
- Smith, J. E., Heath, L. S., Skog, K. E., & Birdsey, R. A. (2006). Methods for calculating forest ecosystem and harvested carbon with standard estimates for forest types of the United States. Gen. Tech. Rep. NE-343. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northeastern Research Station. 216 p., 343. <https://doi.org/10.2737/NE-GTR-343>

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35

Soils of Ashburnham, Fitchburg, Leominster, Pepperell, and Groton

Surficial Geology and Drainage Class

Understanding the geologic history of the Nashua River Watershed reveals the patterns of current and potential soil characteristics. As with most soils in the Northeast, the forces of the last glacial period deposited, sorted, and sifted a base of mineral materials across the landscape. This historical activity has resulted in diverse soil types each with a unique mix of sand, silt, clay, and organic material layered into horizons.

A surficial geology map of the communities, shown on the opposite page, shows two dominant classes of parent materials: the sand and gravel deposits that are the result of historic hydrology and the till and bedrock material of the higher altitude areas of the communities.

Two other classes of parent material are also represented: the fine grained deposits in the floodplain of the Nashua River between Groton and Pepperell, and a dispersed array of post-glacial swamp deposits with significant areas in Ashburnham and Pepperell and most abundantly in Groton.

In the 10 millennia since glacial retreat, the dynamics of

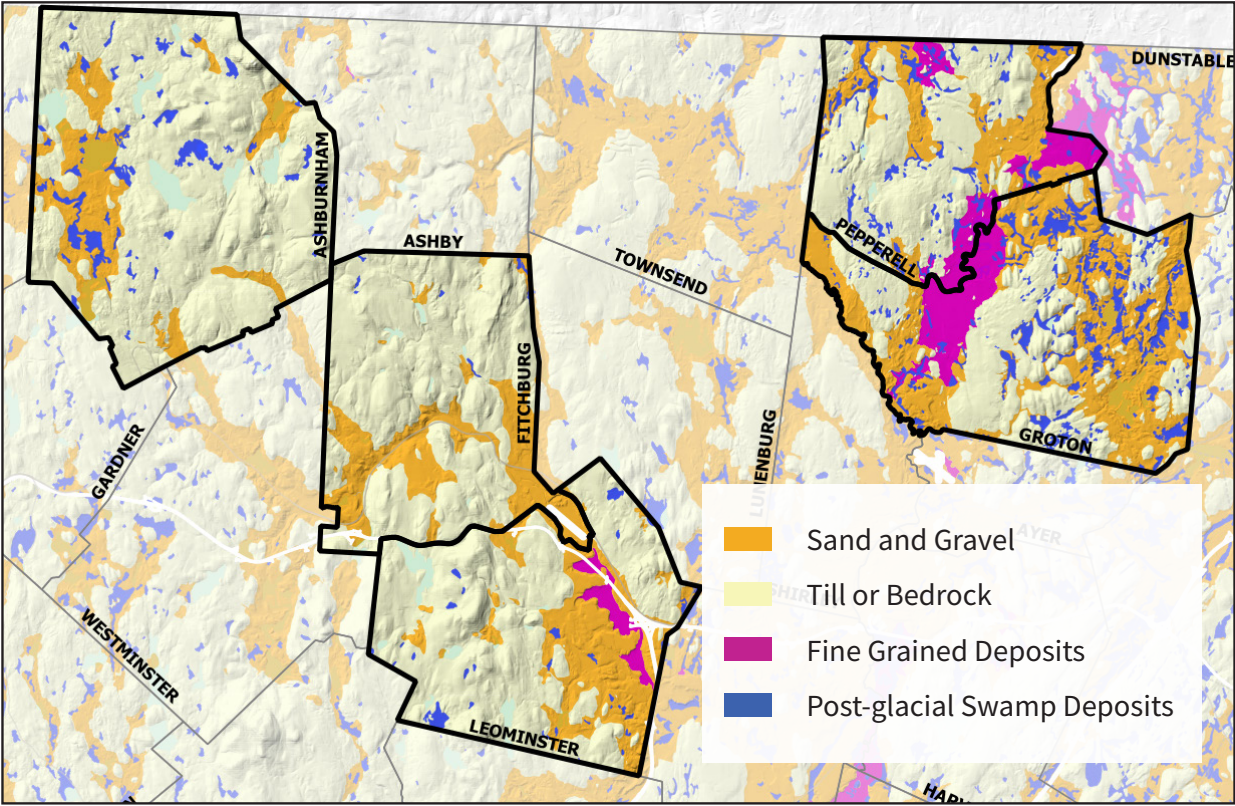
weathering, erosion, deposition, and biology—including human activity—have shaped this material into living soil with a wide range of properties. The diverse soils of these have been classified by the Natural Resources Conservation Service (NRCS) into mapped soil types in different drainage classes. Broad patterns of soil drainage are shown in the "Drainage Class" map on the opposite page.

The following pages reveal how surficial geology has influenced land use patterns and therefore the soil health of the Nashua River watershed. We can see, for instance, how the sand/gravel and the fine-grained parent materials correlate to the more developed areas of the communities.

Drainage Class Area by Municipality

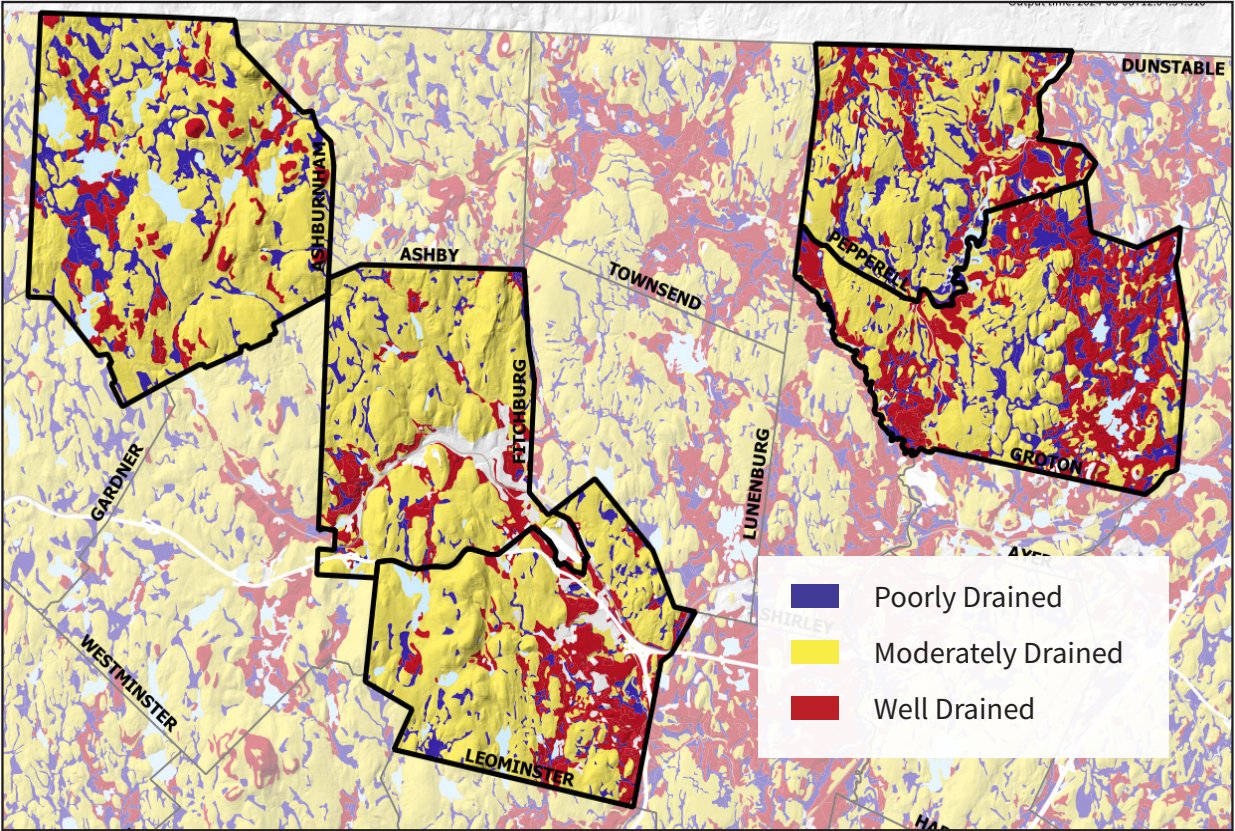
	ASHBURNHAM	FITCHBURG	LEOMINSTER	PEPPERELL	GROTON
<div></div> Poorly Drained	4,107 ac (15.7 %)	1,277 ac (7.6 %)	1,779 ac (9.4 %)	2,826 ac (19 %)	3,834 ac (17.7 %)
<div></div> Moderately Drained	17,153 ac (65.5 %)	12,448 ac (73.9 %)	11,741 ac (61.8 %)	8,149 ac (54.9 %)	9,095 ac (42.1 %)
<div></div> Well/Excessively Drained	3,213 ac (12.3 %)	2,406 ac (14.28 %)	3,981 ac (21 %)	3,300 ac (22.2 %)	7,690 ac (35.6 %)
<div></div> Unknown (likely urban land or land under water body)	1,736 ac (6.6 %)	713 ac (4.23 %)	1,494 ac (7.9 %)	568 ac (3.8 %)	1,001 ac (4.6 %)

Surficial Geology



Surficial geology has a major influence on soil characteristics and function.

Drainage Class



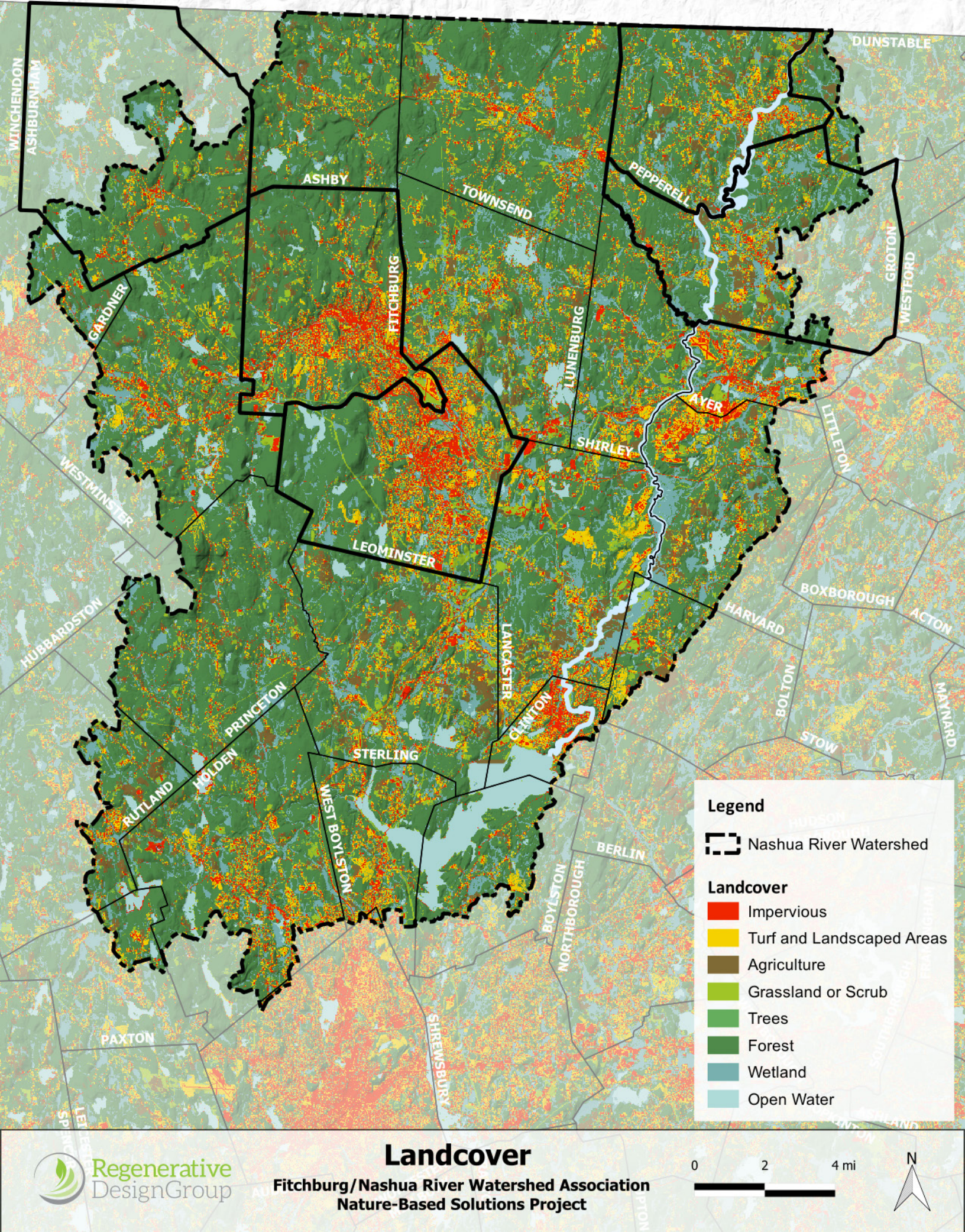
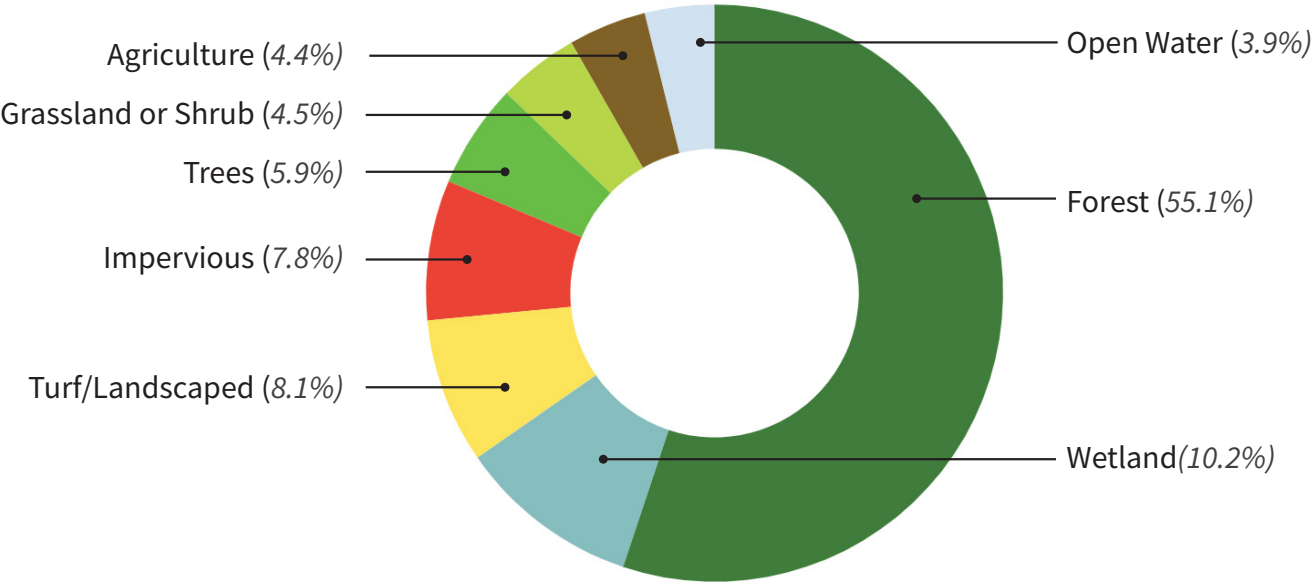


Table 2: Landcover Acreages

Landcover	Ashburnham	Fitchburg	Leominster	Pepperell	Groton
Forest	18,132	9,680	8,322	7,800	11,344
Impervious	887	2,742	3,207	1,006	1,234
Turf and Landscaped Areas	844	1,941	2,381	1,378	1,575
Trees	911	1,469	1,589	1,114	1,331
Wetland	2,601	1,651	1,670	1,832	3,513
Open Water	1,687	237	551	196	624
Agriculture	436	653	325	970	1,296
Grassland or Shrub	710	856	949	529	702

Landcover Breakdown for Nashua River Watershed in Massachusetts



Landcover and Soil Organic Carbon

The five focus communities of this project represent a cross-section of the different land use patterns found throughout the Massachusetts portion of the watershed. Ashburnham is a mostly rural area with a relatively little amount of soil disturbance; Pepperell and Groton have a significant amount of dispersed farmland and residential areas; and Fitchburg and Leominster are the two most highly developed and urbanized communities in the watershed in Massachusetts.

These patterns, and the landscape history that led to them, have a huge influence on dynamic soil properties and the current level of soil health in these communities. Particularly, we can see how landcover influences soil

organic carbon (SOC) stocks by comparing the map above to the SOC map on the following page. The less disturbed forested and wetland areas have high estimated SOC stocks while the more developed and degraded lands are likely to have lower SOC levels. Pockets of carbon-rich soils can be found in the wetlands, with the most significant acreage in Ashburnham, Pepperell, and particularly Groton. This analysis begins to suggest which soils might be most valuable to conserve and which can and should be rehabilitated as discussed in the preceding sections.

Estimated SOC stocks by major landcover categories in each the focus communities are shown in Table 4 on page 41.

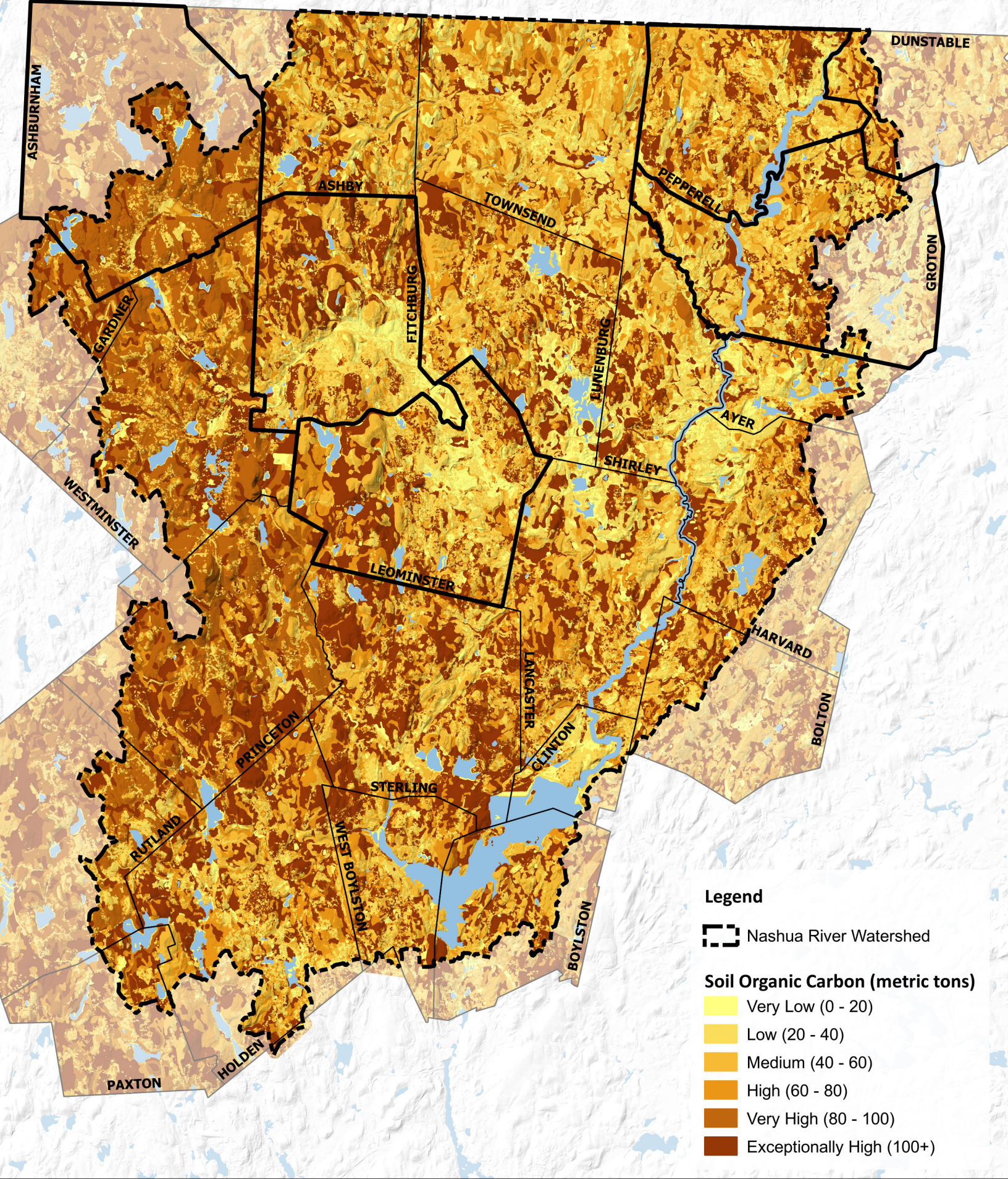


Table 4: SOC Stocks by Landcover (metric tons)

	Ashburnham	Fitchburg	Leominster	Pepperell	Groton
Wetland	626,291	52,815	210,832	239,151	571,765
Forest	1,860,651	1,175,745	986,461	664,026	854,563
Trees	89,194	121,579	130,941	91,153	106,394
Grassland or Scrub	36,696	46,285	56,779	23,402	30,411
Agriculture	19,176	40,684	11,936	46,316	76,968
Turf and Landscaped Areas	34,493	71,399	88,130	49,211	54,928
Impervious	19,720	60,925	71,258	22,349	27,425

This table adds up all of the estimated SOC stocks in each municipality and classifies them by landcover. SOC was estimated using the process outlined on page 42.

Estimating SOC as Soil Health Indicator

Overview

Assessing soil health for a whole municipality or state scale relies on the use of measurable proxy indicators. Soil organic carbon (SOC) was selected as the primary proxy of soil health in this study because of the important effects it has on all soil functions and the wide availability of SOC estimates. The physical characteristics of soil, like texture and structure, largely determine total carbon holding capacity—while land cover and land use influence the rate at which carbon is sequestered in the soil and how long it resides there.

The process used to estimate SOC levels across the Massachusetts portion of the Nashua River watershed combines soil data from the National Cooperative Soil Survey (NCSS), an aggregate of thousands of individual soils tests, with land cover data from MassGIS. Appendix 2 (page 76) provides a detailed description of the methods used to estimate SOC for this project, but below is an overview.

SOC Estimation Process

The NCSS SOC values for each soil unit were derived from a particular representative soil sample under a particular landcover. Because landcover plays a significant role in SOC, we needed to adjust the SOC values to account for the difference between the representative sample and the current landcover.

In non-wetland soils, forest landcover has the highest SOC values; therefore, for all soils that had a representative landcover other than forest, we adjusted the original NCSS SOC values to be in line with forest values. For non-wetland soils, this represents the carbon holding capacity of each soil area. To account for the current landcover in areas other than forest, we reduced the SOC under those landcovers to arrive at a more fine tuned estimate of SOC for all landscapes across the project area.

- Very Low (0-20 tons/acre)
- Low (20-40 tons/acre)
- Medium (40-60 tons/acre)
- High (60-80 tons/acre)
- Very High (80-100 tons/acre)
- Exceptionally High (100+)

Data Sources: Soils SSURGO-Certified NRCS, NRCS Rapid Carbon Assessment, MassGIS 2016 Landcover

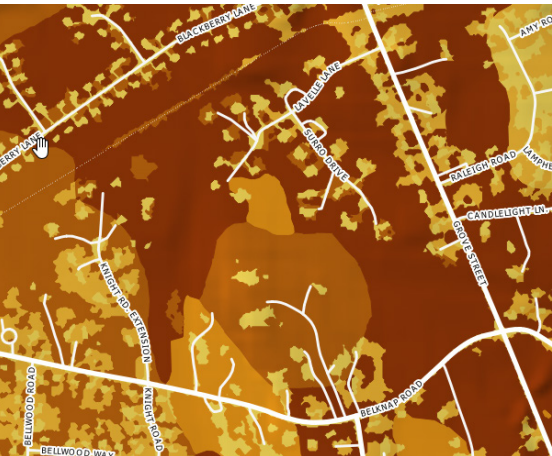
Original NCSS SOC



SOC adjusted to show highest carbon capacity



Current Landcover Adjusted SOC



Opposite: Land cover and land use can have a profound effect on soil carbon and structure. Highly disturbed urban soil show little structure and contains abundant construction debris (Left, M. Payne). A typical cross section of Merrimac soils shows clear horizons and topsoil development (Right, nesoil.com).



APPENDIX 1: SOIL SMART BYLAWS - EXAMPLES FROM DEERFIELD, MA

The following bylaws were written by Chris Curtis of Conservation Works in collaboration with Regenerative Design Group for the Deerfield Healthy Soils Project, which was recognized by the Boston chapter of the American Planning Association with the 2022 Sustainability and Resiliency Award.

DRAFT DEERFIELD CREATIVE DEVELOPMENT BYLAW

Updated 6/15/22

7100. Creative Development

7110. Creative Development Allowed

Creative Development in accordance with this bylaw shall be allowed by Special Permit in any Residential zoning district, except not in the Floodplain District. Any person creating two or more lots available for residential use, whether or not by subdivision may apply for a special permit under this section. Creative Development shall be encouraged within the town, and shall be the preferred method of development wherever the following purposes would be served.

7120. Purpose

The purpose of this bylaw is to encourage creative and innovative development patterns which promote the following:

- A. Preservation or enhancement of rural town character, including scenic roads and town centers;
- B. Provision for alternative to strip residential development lining roadsides in the town, and encouragement of development out of view from the road;
- C. Protection of natural resources, historic or archeological structures or sites, or scenic views;
- D. Protection of open space for use as farmland, woodlot or forestry, recreation, or wildlife habitat;
- E. Provision of affordable housing, or housing for the elderly, handicapped, or others with special needs.

7130. Criteria for Evaluation

No special permit for Creative Development shall be issued unless the application therefore complies substantially with the following criteria:

- A. All dwellings shall, to the greatest extent possible, be located out of view from any road unless valuable natural resources or farmland located to the rear of the property render building in view of the road more desirable.
- B. The Creative Development shall create permanent open space. All land within the Creative

Appendices

Development not in use for building lots shall be placed in permanent open space.

- C. The portion of a parcel placed in open space shall, to the greatest extent possible, be that which is most valuable or productive as a natural resource, wildlife habitat, farmland, or forestry land.
- D. The Creative Development shall result in the creation of less curb cuts or vehicular access points to a public way than would reasonably be expected to occur under Standard ANR or Subdivision Development.
- E. The Creative Development shall result in no net increase in density of dwellings on the parcel over the density which could reasonably be expected to occur on the parcel under Standard ANR or Subdivision Development.

7140. Terms of Special Permit

Any Special Permit for Creative Development shall state clearly the terms by which the development shall meet the above-listed criteria. The Special Permit granted shall state the acreage and location of open space provided; shall identify the natural resources or farmland to be protected and any specific measures to be taken for their protection; shall specify the number and location of dwellings and curb cuts; and shall state the number of units, if any, to be constructed, including their location and the method by which their creation shall be assured, such as by covenant or easement.

7150. Definitions

Creative Development: shall mean a form of residential development allowed in all districts by special permit, whereby the options of common driveways and flexible area and frontage requirements are utilized to create permanent open space and avoid standard ANR and subdivision development.

Common Driveway: shall mean a vehicular access from a road to more than one but no more than six residential units, built in accordance with the common driveway standards stated below, where allowed by special permit.

Affordable Housing Units: are those dwelling units which may be purchased by individuals or families with incomes between 80% and 120% of the median income for the Standard Metropolitan Statistical Area, provided that expenditure for housing costs does not exceed 30% of the gross annual income of the purchaser.

Housing Costs: for affordable housing units shall mean the annual payments necessary based on current available mortgage interest rates, a 30-year mortgage term, and a 10% down payment.

Median Income: shall mean the median income figure established for the applicable Standard Metropolitan Statistical Area, as established by annually updated U.S. Department of Housing and Urban Development median gross family income data.

7160. Common Driveways

- A. Common Driveways Allowed - Common Driveways shall be allowed by Special Permit in accordance with the provisions of this section. Where applicable, under the Subdivision Regulations, common driveways may be allowed in place of a subdivision road.
- B. Up to Six Lots Served - No more than six lots shall be served by a common driveway. The driveway shall lie entirely within the lots being served.
- C. Driveway Not to be Used as Frontage - Frontage along the length of any common driveway shall in no way be used to satisfy frontage requirements as specified in the Zoning Bylaw; furthermore, no common driveway shall be accepted as a public road; nor shall the town under any circumstances be held liable for construction, reconstruction, maintenance, or snow removal on any common driveway, unless by contract duly entered into by the town and all landowners served by the common driveway.
- D. Driveway Right-of-Way - The landowners of all residences served by a common driveway shall be granted a Right-of-Way for the use of the common driveway. Such Right-of-Way shall be recorded in the Hampshire County Registry of Deeds, together with a statement of covenants as follows:
 - (1) The common driveway shall at no time be used to satisfy frontage requirements under the zoning bylaw;
 - (2) The common driveway shall at no time become the responsibility or liability of the town;
 - (3) Each landowner served by the common driveway shall be liable and responsible in whole for the repair and maintenance of any portion of the common driveway to which they have the exclusive Right-of-Way (such as a spur serving solely one parcel); and
 - (4) Each landowner served by the common driveway shall be jointly and severally responsible and liable for the repair and maintenance of all portions of the common driveway to which more than one landowner holds a Right-of-Way.
- E. Common Driveway Standards
 - (1) Alignment and Dimensions
 - a. The width of the right of way shall be 40 ft.

- b. The minimum width of the common driveway surface shall be 18 ft.
- c. The common drive shall have 3 ft. gravel shoulders on each side.
- d. The slope or grade of a common drive shall in no place exceed 8% if unpaved; or 12% if paved.
- e. The common drive shall intersect a public way at an angle of not less than 80 degrees.
- f. The minimum curvature of a common driveway shall be sufficient for a fire engine to negotiate, generally no less than a radius of 50 ft.
- g. There shall be a turnaround area at the resident end of the driveway such turnaround shall accommodate safe and convenient turning by fire trucks and other emergency vehicles.
- h. The maximum length of a common driveway shall be 500 feet.
- i. Other standards may be set based on site configurations, including requirements for drainage.
- j. These standards may be waived when, in the opinion of the Planning Board, such action is in the public interest and not inconsistent with the purpose and intent of the Zoning Bylaw.

(2) Construction

- a. The common driveway shall be constructed of a minimum 15" gravel base with an oil and stone top layer of 1/2" consisting of three successive layers of 3/4" crushed traprock stone, 1/2" crushed traprock stone and 1/4" crushed traprock stone, with a crown sufficient for drainage.
- b. Drainage shall be adequate to dispose of surface runoff. Culverts shall be installed if deemed necessary by the Planning Board.
- c. These construction standards may be waived if, in the opinion of the Planning Board, such action is in the public interest and not inconsistent with the purpose and intent of the Zoning Bylaw.

(3) Alignment and Dimensions

- a. The common driveway, at its intersection with the street, must provide a leveling-off area with a slope no greater than 1% for the first 20 feet and a slope no greater than

5% for the next 30 feet.

- b. Minimum safe sight distance must be provided at the intersection of a common driveway with a street.
- F. Street Numbers and Identification - Each common driveway shall be assigned one street number; each residence served by the common driveway shall be assigned a letter to use together with the common driveway number for purposes of address and identification. All common driveways shall be clearly marked at the intersection of the driveway and the frontage road by a sign stating the driveway number, house letters, and names of house residents, sufficiently readable from the road to serve the purpose of emergency identification. The fire chief and/or highway department may make more specific requirements for driveway marking.
- G. Home offices, home occupations, bed and breakfasts, and other home business uses may be permitted in any dwelling served by a common driveway where the dwelling containing such home business has at least 200 foot frontage on an approved road, and is otherwise shown not to cause nuisance to adjoining landowners and other landowners sharing the common driveway.
- H. There shall be a minimum of 400 feet between the entrances of any two common driveways onto any road.
- I. Common driveway design shall to the greatest extent possible minimize adverse impact to wetlands, farmland, or other natural resources; allow reasonable, safe, and less environmentally damaging access to lots characterized by slopes or ledges; and result in the preservation of rural character through reduction of number of access ways; and retention of existing vegetation and topography.

7170. Creative Development Using Flexible Area and Frontage Standards

- A. Creative Developments shall utilize the flexible area and frontage provisions of this bylaw, in coordination with Section 7160 regarding Common Driveways, for the purpose of minimizing the destruction of natural resources while maximizing availability of open space, farmland, and rural character.
- B. Flexible Frontage in Creative Developments
 - (1) The frontage of the parcel from which the lots of a creative development are created (whether or not by subdivision) shall equal or exceed one half the total frontage length otherwise required for the sum of all lots created as shown in the Table of Creative Development Dimensional Requirements (Table 1). For example, to create a six-lot creative development in a Residential Zone where there is a 175 foot frontage

requirement, the parcel must have a minimum of 525 foot contiguous frontage along one road.

- (2) Provided that all other requirements of this bylaw are met, there shall be no frontage required for individual lots within a Creative Development, with the exception described in Section 7170(B)(3) below.
- (3) Any building lot which fronts on an existing public road shall have the frontage required in the Table of Dimensional Regulations. This provision shall not apply to protected open space.

C. Flexible Area in Creative Developments

- (1) Individual lot areas may be as small as the minimum lot sizes shown in Table 1, provided that the average size for all lots created, including any land reserved as open space, shall be no smaller than the required average lot size, shown in Table 1.
- (2) The total number of building lots which can be created from any parcel shall be determined by dividing the total parcel area by the required average lot size shown in Table 1.
- (3) All land not used for building lots shall be placed in permanent open space in accordance with Section 7200 of this bylaw, but not less than 25% of the total land area.
- (4) Estate or Flag Lots shall not be permitted in a Creative Development.

D. Other Dimensional Requirements

All lots within a Creative Development shall meet the front, rear and side yard requirements specified in Table 1.

E. Site Design Standards

Each structure shall be integrated into the existing landscape on the property so as to minimize its visual impact through use of vegetative and structural screening, landscaping, grading, and placement on or into the surface of the lot.

7180. Creative Development Using Farmland Preservation Standards

Where a parcel for which a special permit under this bylaw is sought is presently used for agriculture, the preferred method of residential development shall be as follows:

- A. All lots to be used for residential development shall be of the minimum area permitted under this bylaw as shown in Table 1. All land not used for residential building lots shall be

permanently preserved as open space in accordance with Section 7200. At least one-half of the total parcel shall be so preserved.

- B. The total parcel frontage required shall be determined in accordance with the flexible frontage standards described in Section 7170 and Table 1.
- C. All buildings, roads and driveways shall be located away from soils which are most suitable for agriculture (based on U.S. Soil Conservation Service classifications for prime farmland soils and soils of state and local importance) to the maximum practical extent. This provision does not apply to the location of on-site septic disposal facilities which must be placed in soils meeting the Massachusetts Environmental Code.
- D. All roads, driveways, drainage systems and utilities shall be laid out in a manner so as to have the least possible impact on agricultural lands and uses.
- E. All buildings, homes, and structures shall be located a minimum of 100 feet from agricultural land and shall be separated from agricultural uses by a 75-foot wide buffer strip of trees and fencing sufficient to minimize conflicts between farming operations and residences.
- F. All Creative Developments under this section shall comply with the dimensional standards in Section 7170(D) and site design standards in Section 7170(E).

7190. On-Site Sewage Disposal

The following standards shall apply to developments requiring on-site sewage disposal:

- A. The applicant shall submit a septic system design prepared by a certified engineer and approved by the Board of Health and a plan illustrating the location of water supply wells with the special permit application. Septic systems shall be placed in the development to maximize the distance between systems.
- B. No Creative Development shall be approved unless the applicant can demonstrate to the satisfaction of the Planning Board that the potential for groundwater pollution is no greater from the proposed creative development than would be expected from a conventional subdivision with single-family houses on lots meeting the normal size requirements located on the same parcel.

7200. Protection of Open Land

The following standards shall apply to open land to be protected as part of a Creative Development:

- A. All remaining open land shall be permanently protected by one of the following methods:

- (1) A permanent conservation easement or deed restriction conveyed to the town with town approval or to a non-profit trust or conservation organization whose principal purpose is to conserve farmland or open space. At a minimum, such an easement or restriction shall entail the use of management practices that ensure existing fields or pastures, if any, will be plowed or mowed at least once every year.
- (2) Ownership in fee simple conveyed to the Town with Town approval or to a non-profit farm trust, open space or conservation organization as a gift or for consideration.
- (3) If the protected open space is farmland, farmland owners are not required to sell the part of their property which is to become permanent agricultural open space, provided that they do convey the development rights of that open space in a conservation easement prohibiting future development of this property to Town with Town approval or to a non-profit trust or conservation restriction.
- B. A non-profit, homeowner’s association shall be established, requiring membership of each lot owner in the Creative Development. The association shall be responsible for the permanent maintenance of all community water and wastewater systems, common open space, recreational and thoroughfare facilities. A homeowner’s association agreement or covenant shall be submitted with the special permit application guaranteeing continuing maintenance of such common utilities, land and facilities, and assessing each lot a share of maintenance expenses. Such agreement shall be subject to the review and approval of Town Counsel and the Planning Board.

7210. Creative Development with Affordable Housing

- (1) A Creative Development with Affordable Housing shall be defined as any creative development which includes 25% or more of its units for low and/or moderate income people and which is subsidized by federal, state or local programs, or proposed by the Housing Authority, or by a non-profit or limited dividend partnership, or any development which includes non-subsidized housing units priced to be affordable to people whose income is equal to or less than 120% of the median income for the Standard Metropolitan Statistical Area and which provides that the mix of affordable and market rate housing built in any one year is equivalent to the overall mix for the entire development, and which further provides that resale restrictions are established by the developer which ensure that the affordable units remain affordable for a period of forty years.
- (2) For a Creative Development with Affordable Housing, the Special Permit Granting Authority may reduce the requirement in Table 1 for the protection of permanent open space to 10% of the total parcel, and may reduce the total parcel frontage required to 75% of the frontage requirements in Table 1.

TABLE 1 - TABLE OF CREATIVE DEVELOPMENT DIMENSIONAL REQUIREMENTS					
DEVELOPMENT TYPE	LOT SIZE**	REQUIRED OPEN SPACE	TOTAL PARCEL FRONTAGE REQUIRED	FRONT YARD	SIDE YARD
Standard Subdivision or ANR Development	60,000 in RA District	None	200 ft per lot in RA District	30 ft. in RA District	10 ft. in RA District
Creative Development - Using Flexible Area	30,000 sq. ft. minimum* and 60,000 sq. ft. average in RA District	All land not used for building lots; minimum 25% of the parcel	85 ft. per lot in RA District	20 ft. from a common driveway, 150 ft. from a public way	10 ft. in RA
Creative Development - Using Farmland Preservation Standards	30,000 sq. ft. in RA District.	Minimum 50% of the parcel	85 ft. per lot in RA District	20 ft. from a common driveway 150 ft. from a public way	10 ft. in RA
* provided that average lot size requirements for creative development are met after wetlands and slopes greater than 15% have been excluded, provided that open space requirements are met.					
** per dwelling unit					

PROPOSED DEERFIELD ZONING BYLAW for POST CONSTRUCTION SOIL PERFORMANCE STANDARDS

Updated 6-15-22

Amend the Site Plan Review bylaw, Section 5400, as follows:

Modify Section 54892 as follows:

54892. Construction Waste Management and Topsoil Recovery

Applicants shall demonstrate that the development will, to the extent feasible, minimize construction waste and loss of topsoil resulting from demolition, construction and land disturbance activities.

- a. To the greatest extent feasible, recycle or salvage non-hazardous construction and demolition debris, including waste cardboard, metal, brick, acoustical tile, concrete, plastic, clean wood, glass, gypsum wall-board, carpet and insulation.
- b. Provide details on construction waste management and topsoil recovery, including identification of all materials that will be diverted from final disposal for reuse on site, charitable donation, and recycling.
- c. To the extent feasible, preserve and re-apply at least 6” of the site’s topsoil and at least 12” of the site’s subsoil to replicate pre-existing conditions. **Comply with Post Construction Soil Performance Standards in Section 54893.**

Add a new Section 54893 as follows:

54893. Post Construction Soil Performance Standards

All projects requiring Site Plan Review under Section 5400 shall comply with the “Guidelines for Post Construction Soil Performance”, adopted by the Planning Board, and found under Deerfield Planning Board Regulations.

Planning Board Regulations, to be adopted by vote of Deerfield Planning Board:

Guidelines for Post Construction Soil Performance

a. Planning and Construction Practices

- 1) Assess the Soil Resources of the Site. Perform pre-construction soil testing in green field developments and/or reference the NRCS Soil Survey where available. In urbanized or heavily disturbed soils attention to potential contamination is essential.

- 2) Limit Disturbance. Preserve natural vegetation on the site, especially mature trees and their rooting zones.
- 3) Limit and Mitigate Compaction:
 - (a) Sub-soil compaction at the site must be broken up to a depth of at least 10 inches below the surface or to bedrock if this is shallower than 10", or
 - (b) Restore the soil to " The depth of the 0 and A horizons on the NRCS Official Soil Series Description of the native mapped soils"
- 4) Soil Quality and Plantings:
 - (a) The site must have a pH, organic matter levels, and nutrient profile suitable for the proposed planting plan.
 - (b) Soil compaction. The topsoil and upper portion of the subsoil must allow for easy water absorption and root penetration. Compaction, as measured with a penetrometer across the site, must not exceed 300 psi in 50% of sample points within top 15” of the soil.
 - (c) Plantings must be successfully established prior to final sign-off. A 2-3 year establishment period is recommended.
- 5) Options for Achieving Excellent Soil Health within Construction Sites: Once construction is near to complete, reestablishing soils and vegetation can proceed.
 - (a) Option 1: Amend existing site topsoil or subsoil in place.
 - (b) Option 2: Remove and stockpile existing topsoil during grading, using improved stockpiling practices.
 - (c) Option 3: Import topsoil mix, or other materials for mixing, including compost, of sufficient organic content and depth (specified elsewhere)

b. Site Preparation

- 1) Preparation and Undisturbed Area Protection
 - (a) Conduct soil survey within construction boundary to 1-m depth to establish existing soil depth, texture, organic matter, and compaction levels. If already disturbed by previous construction, refer to NRCS Soil Web Survey to identify typical soil profile for the project site. Use the texture, horizons, and other attributes from this profile as reference for post construction performance.
 - (b) Establish a clear construction boundary that protects existing trees, other vegetation, and minimizes soil disturbance.
 - (c) Work with contractors and other service providers to ensure they understand they are forbidden from stockpiling materials, driving, or storing vehicles outside of the area of work without permission in writing from landscape architect or client agent.
 - (d) Erect construction fencing and erosion controls where specified at construction boundary.

c. Excavation

- 1) Remove and stockpile all topsoil to the bottom of the A-horizon (the topsoil) following stockpile protocols below.
- 2) Excavate subsoil as required to enable placement of structures, paving, and site improvements, and from areas to be regraded. Stockpile subsoil separately from the topsoil following the protocols below.

d. Soil Stockpiling Protocol

- 1) Preparation:
 - a. Protect all soils to be stockpiled on site from contamination of toxic substances, noxious weeds, or other contaminants.
 - b. Separate topsoil from subsoil during excavation and stockpiling
 - c. Screen topsoil to remove large or matted roots, vegetation, debris, and rocks over 2 inches.
- 2) Storage:
 - a. Ensure proper aeration and moisture levels of stockpiles to prevent anaerobic conditions from occurring during storage
 - i. Avoid stockpiling in wet areas
 - ii. Do not exceed piles greater than 5’ tall and 10’ wide, where feasible
 - iii. If stockpiles must exceed these dimensions, include aeration piping consisting of 3-4” perforated pipe spaced no more than 5’ in any dimension
 - iv. In dry conditions, irrigate to keep vegetation alive and soil garden-moist
 - b. Maintain Cover : Protect stockpiles from degradation by keeping covered
 - i. **Minimum practice:** Cover with air-and-water permeable cover, e.g. jute mat or compost felt.
 - ii. **Better:** Seed with temporary crop like annual rye or crimson clover. Living plants help maintain biological communities of soil.
 - iii. **Best:** Consult soil test and amend stockpiles with rock minerals to address deficiencies and biochar to increase durable carbon. Plant with temporary cover.

matter. It should be possible to reduce use of irrigation, fertilizers, herbicides and pesticides. These activities should be adjusted where possible, rather than continuing to implement formerly established practices.

e. During Construction

- 1) Monitor excavation to ensure retention and protection of native topsoil & vegetation wherever designated.
- 2) Monitor disturbance boundaries: Repair construction fencing and erosion controls at the limits of the area of work as necessary. Discuss issues with contractors.
- 3) Remove and stockpile soils, as specified above, within area of work.
- 4) Rough grade areas to required slopes (grades) and elevations as specified on plan and to meet criteria:
 - a. Adjust contours to eliminate water ponding and provide positive drainage.
 - b. Make grade changes gradually.
 - c. Blend slopes into level areas and undisturbed areas.
- 5) Break-up compacted subsoil to a depth of 12” below the surface or to bedrock.*
- 6) Till 2-3" of compost into poor quality site soils, or as specified by landscape architect*
- 7) Install 6” to 8" of compost- amended topsoil where necessary. Specifications to be provided by landscape architect.*
- 8) Apply seed, hydromulch, and other erosion controls, as specified, immediately following finish grading.
- 9) Mulch landscape beds with 3-4” of natural mulch, or other specified material, immediately after planting.
- 10) Protect restored soils from erosion or re-compaction by heavy equipment.

f. Follow-up and Maintenance

Soil quality and depth should be established toward the end of construction and once established, should be protected from compaction (such as from large machinery use) and from erosion. Soil should be planted and mulched after installation. Plant debris or its equivalent should be left on the soil surface to replenish organic

3900. Transfer of Development Rights

Draft bylaw for Town of Deerfield, updated 6-15-22

3910. Purposes.

The purposes of this bylaw are:

- 1) To permanently protect farmland, forest land and healthy soils in the Town of Deerfield.
- 2) To protect farmland and forest land property values and provide a fair economic return to owners of property restricted from further development.
- 3) To foster compact and mixed use, smart growth and development in village center areas served by public infrastructure.

3911. Establishment of Farmland and Forest Preservation (Sending) District and Village Center (Receiving) District.

The following overlay zoning districts are hereby established:

39111. Farmland and Forest Preservation (Sending) District: This district shall consist of all land within the Residential-Agricultural Zone.

39112. Village Center (Receiving) District: This district shall consist of all land within the CVRD, C-I and C-II Zoning Districts.

3912. Transfer of development rights.

Transfer of development rights provides for increased density of residential or commercial development in the designated Village Center (Receiving) District when suitable open space land in the Farmland and Forest Preservation (Sending) District is permanently preserved from development. The transfer of development rights is accomplished by the execution of an agricultural preservation restriction, and the increased density is permitted by the issuance of a special permit, both as hereinafter provided.

3913. Eligibility.

All lots shown on a plan, or described in a deed, recorded at the Registry of Deeds in the Farmland and Forest Preservation (Sending) District are eligible to apply for a special permit from the Planning Board to transfer all or part of the development rights, certified under Section 3915 of this bylaw, on the lot to a lot in a Village Center (Receiving) District.

3914. Village Center (Receiving) District regulations.

39141. To be eligible for transfer of development rights, a special permit with site plan approval from the Planning Board is required.

39142. The Planning Board may permit an increased number and density of buildings

in the Village Center (Receiving) District as part of a special permit for transfer of development rights, in accordance with Section 3916 of this bylaw.

3915. Process for certifying development rights.

39151. Eligible landowners (individuals that own land in the Farmland and Forest Preservation (Sending) District) may submit an application to the Planning Board for certification of available development rights on their property. The applicant shall determine the number of acres of land eligible for transfer from the parcel in the Farmland and Forest Preservation (Sending) District.

39152. The Planning Board shall review the applicant's assessment of acreage eligible for transfer and shall make a final determination of such acreage eligible for transfer. Within 45 days of receiving an application, the Planning Board shall issue a TDR certificate to the applicant that states the number of certified development rights that are available for transfer. This certification shall in no way serve as determination of the number of lots in a standard development. Each acre so certified shall constitute one certified development right unit.

3916. Special permit process for transfer of development rights.

39161. The applicant proposing to develop specified land in the Village Center (Receiving) District at a density allowed by this bylaw with a transfer of development rights shall make application to the Planning Board for a special permit with site plan approval. The application shall clearly illustrate a land parcel or parcels in the Farmland and Forest Preservation (Sending) District and a land parcel or parcels in the Village Center (Receiving) District proposed for transfer of development rights and the number and form of development rights proposed for transfer, in accordance with the provisions of Section 3917. The application shall also show that the applicant has an option to purchase certified development rights for the proposed transfer.

39162. The applicant shall submit to the Planning Board a transaction fee, to be used for the administration, recording and monitoring of the transferred development rights and preserved agricultural preservation restriction. The Planning Board may employ a consultant for these administrative purposes. This fee may be in addition to an application fee.

39163. The applicant shall also file with the Planning Board a preliminary development plan for the parcel in the Village Center (Receiving) District, illustrating how the transferred development rights will be used.

39164. Prior to final approval of a special permit, the applicant shall tender to the Planning Board a valid instrument granting to the Town a permanent agricultural preservation restriction or conservation restriction for eligible land in the Farmland and Forest Preservation (Sending) District. The developer shall furnish to the Planning Board a certificate of title by a duly licensed attorney and such other evidence or assurance of title as may be satisfactory to the Town Counsel.

39165. Upon advice of the Town Counsel that the agricultural preservation

restriction or conservation restriction document is valid and sufficient, there must be a vote by the Board of Selectmen authorizing Conservation Commission acceptance of the agricultural preservation restriction or conservation restriction. If the special permit application is valid and sufficient, the Conservation Commission, acting on behalf of the Town, shall accept the agricultural preservation restriction for signature of the Massachusetts Commissioner of Agriculture in the same manner as other APRs, or shall accept the conservation restriction. Documents shall be recorded in the County Registry of Deeds. Upon final approval of site plans, the Planning Board shall issue a special permit permitting development of the specified land at the approved density, based on the table in Section 3917.

3917. Dimensional and density regulations.

39171. Each acre of land within the Farmland and Forest Preservation (Sending) District is equivalent to one of the development rights in the Village Center (Receiving) District shown in the Table of Exchange Standards for Transfer of Development Rights, found below in this section.

39172. The maximum limits on density, lot coverage, and parking reductions permitted to be developed by special permit in the Village Center (Receiving) District shall be determined by reference to the Table of Exchange Standards for Transfer of Development Rights, found below in this section.

TABLE 1. EXCHANGE STANDARDS FOR TRANSFER OF DEVELOPMENT RIGHTS

Farmland and Forest Preservation (Sending) District	Village Center (Receiving) District	Notes
1 PRESERVED ACRE OF LAND IN THE SENDING ZONE EQUALS:	A 5% increase in maximum building coverage for a single residential, commercial or industrial lot	1) The Planning Board may allow an increase in building coverage up to the maximum building coverage shown in Table 2 - Dimensional Regulations.
OR	A reduction in required parking of twenty commercial parking spaces, or	4) The Planning Board may reduce the minimum parking requirements in Section ____ of the Zoning Bylaw for off-street parking area. The Planning Board may reduce this requirement for off-street parking area to a minimum of 75% of the required parking. To obtain this waiver, the applicant shall demonstrate that sufficient parking will be available to the development (i.e. through shared parking, use of on-street parking, reduced vehicle use, timing, etc.).
OR	an increase of 5 feet in building height, or	5) The maximum increase in building height shall be 15 feet.
OR	A reduction in minimum front setback requirements of five feet	6) The maximum reduction in front setback requirements shall be five feet.
OR	A reduction in minimum side or rear yard requirements of five feet.	6) The maximum reduction in side or rear yard requirements shall be five feet.
OR	A reduction of 20 feet in frontage requirements.	6) The maximum reduction in frontage requirements shall be 40 feet.
5 PRESERVED ACRES IN THE SENDING ZONE EQUALS:	1 mixed use village center development lot	See Section 3950 for regulations governing Mixed Use Village Center Development.

39173. When a landowner wishes to sell less than the total number of development rights available to a tax parcel, he may do so provided that:

- a) The tax parcel is subdivided.
- b) No new parcel less than 10 acres may be created through such subdivision.
- c) The subdivision plan shall specify the agricultural class of all the soils on the site.

TABLE 2. TDR DIMENSIONAL STANDARDS FOR RECEIVING AREAS

Underlying Zoning District	Dimensional Requirements in Underlying Zone	Dimensional Requirements in Village Center (Receiving) District (with TDR)
CVRD Center Village Residential	Min. Lot Size: 12,000 s.f. Min. Frontage: 100 ft. Min. Front Setback: 30 ft. Min. Side Setback: 10 ft. Min. Rear Setback: 10 ft. Max. Lot Coverage: 75% Max. Height: 35 feet	Min. Lot Size: 10,000 s.f. Min. Frontage: 80 ft. Min. Front Setback: 25 ft. Min. Side Setback: 10 ft. Min. Rear Setback: 10 ft. Max. Lot Coverage: 85% Max. Height: 50 feet
C-I Small Business	Min. Lot Size: 15,000 s.f. Min. Frontage: 125 ft. Min. Front Setback: 20 ft. Min. Side Setback: 10 ft. Min. Rear Setback: 10 ft. Max. Lot Coverage: 70% Max. Height: 35 feet	Min. Lot Size: 10,000 s.f. Min. Frontage: 80 ft. Min. Front Setback: 15 ft. Min. Side Setback: 10 ft. Min. Rear Setback: 10 ft. Max. Lot Coverage: 85% Max. Height: 50 feet
C-II Commercial	Min. Lot Size: 30,000 s.f. Min. Frontage: 200 ft. Min. Front Setback: 50 ft. Min. Side Setback: 25 ft. Min. Rear Setback: 25 ft. Max. Lot Coverage: 60% Max. Height: 35 feet	Min. Lot Size: 15,000 s.f. Min. Frontage: 120 ft. Min. Front Setback: 40 ft. Min. Side Setback: 15 ft. Min. Rear Setback: 15 ft. Max. Lot Coverage: 75% Max. Height: 50 feet

3918. Special permit criteria.

The Planning Board shall not grant any special permit for transfer of development rights unless it finds the following criteria are met:

- 39181. The proposed use is in harmony with the purposes in Section 3910 of this bylaw.
- 39182. The proposed use meets all of the procedural, dimensional and density requirements and design standards in Sections 3917 of this bylaw.

3919. Reporting of TDR transactions.

Buyers and sellers must report all TDR transactions (options, sales, gifts, donations) to the

Planning Board within 10 business days.

3920. Release of agricultural preservation restriction.

No agricultural preservation restriction which has been conveyed under this bylaw may be released unless the provisions for release of agricultural preservation restrictions in MGL c. 184, § 32 have been met, which include:

- 39201. The restriction must be repurchased from the Town by the landowner at its then fair market value, and funds must be returned only to the Town bank for development rights.
- 39202. The restriction shall be released by its holder only if the land is no longer deemed suitable for agricultural or horticultural purposes and if approved by a two- thirds vote of both branches of the Massachusetts General Court.

3921. Alternate method for TDR transactions.

In lieu of transferring development rights using the process described in Sections 3912-3916 above, an applicant for a special permit in Section 3916 may make a cash contribution to the Town of Deerfield to be used for the purpose of purchasing agricultural preservation restrictions. The contribution shall be of a value equal to the value of the required development rights, as determined in the Table of Exchange Standards for Transfer of Development Rights. This value shall be determined by multiplying the number of acres of developable farmland required by the average cost for the purchase of agricultural preservation restrictions in the Town of Deerfield over the last three years, as determined by the Conservation Commission.

3922. Biannual review.

The Planning Board shall conduct a biannual review of this bylaw at an advertised public meeting in order to assess the bylaw. The Planning Board shall make recommendations to the Town for any changes needed in the bylaw structure or process.

3923. Bank for development rights.

The Town may purchase development rights for the purpose of sale or use in the Village Center (Receiving) District, or for retirement, after a vote of Town Meeting.

3950. Mixed Use Village Center Development

3951. Purposes

39511. The purposes of this bylaw are to foster a greater opportunity for creative development by providing guidelines which encourage a mix of uses compatible with existing and neighboring properties; to provide housing and business uses in locations where a variety of town services are available; to promote utilization of existing buildings and property, and to encourage the provision of open areas. The intent, furthermore, is to

encourage interaction among activities located within a Mixed Use Development, to enhance business vitality, reduce vehicular traffic, provide employment opportunities for residents close to home, ensure the compatibility with each other of the commercial, and residential uses, ensure that the appearance and effects of buildings and uses are harmonious with the character of the area in which they are located by:

1. Allowing a diversity of uses in close proximity in the district within a limited area, including residential, retail, and office;
2. Accommodating mixed-use buildings with neighborhood-serving retail, service and other uses on the ground floor and residential units above;
3. Encouraging development that exhibits the physical design characteristics of pedestrian-oriented storefront-style shopping streets;
4. Promoting the opportunity for people to work, meet, shop and utilize services in the vicinity of their residences,
5. Providing opportunities for the development of affordable housing,
6. Providing opportunities for a mixture of uses in the same building,
7. Promoting a positive pedestrian environment in the district,
8. Facilitating integrated physical design,
9. Promoting a high level of design quality,
10. Encouraging the development of flexible space for small and emerging businesses,
11. Facilitating development proposals responsive to current and future market conditions, and
12. Encouraging the development of open spaces and parks within the district to accommodate workers, residents, pedestrians, and shoppers.

3952. Special Permits with TDR

39521. Mixed Use Village Center Development are permitted by Special Permit with Site Plan Review and Transfer of Development Rights in the Village Center (Receiving) District accordance with the provisions of this section.

3953. Definitions

39531. The following definitions shall apply to all mixed use applications under these zoning Bylaws/Ordinances:

Assisted Living: Housing for adults, with services provided, such as meals, laundry, and housekeeping.

Business Services: Services used in the conducting of business and commerce, including only: Consumer and mercantile credit reporting; News services; Research, development and testing; Business management and consulting; Insurance company service offices; Real estate offices.

Café: A coffee house or small restaurant, often with an enclosed or outdoor section extending onto the sidewalk.

Cocktail Lounge: Is the use of a site for retail sale of alcoholic beverages for consumption on the premises, including taverns, bars, and similar uses, other than a restaurant use as that term is described in this section.

Driveway: A space, located on a lot, built for access to a garage or off-street parking or loading space.

Fast Food Restaurant: An establishment whose principal business is the sale of pre-pared or rapidly prepared food directly to the customer in a ready-to-consume state for consumption either within the restaurant building or off the premises. Orders are not generally taken at the customers table, and food is generally served in disposable wrapping or containers.

Live-work Units: A live/work unit is defined as a single unit (e.g., studio, loft, or one bedroom) consisting of both a commercial/office and a residential component that is occupied by the same resident. The live/work unit shall be the primary dwelling of the occupant.

Mixed Use Development: The development of a tract of land, building, or structure with two (2) or more different uses such as, but not limited to, residential, office, retail, institutional, or entertainment, in a compact village form, with vehicular access to an accepted public way. A proposed Mixed Use Development shall demonstrate that the project shall be served by town water and sewer service upon completion of the proposed development.

Municipal Facilities: Facilities utilized in the provision of services normally provided by municipalities such as schools, parks, playgrounds, municipal office buildings, and maintenance buildings.

Personal Services: Establishments primarily engaged in providing services involving the care of a person or his/her apparel, including but not limited to: Laundering, dry cleaning and garments services not exceeding 5,000 square feet of floor area per establishment; Coin operated laundries; Shoe repair; Photographic services; Beauty and barber shops;

Apparel repair and alteration; Funeral services; Steam baths; Reducing salons and health clubs; Clothing rental.

Professional Services: Services performed by professional persons for business and personal use, including, but not limited to:

- a. Medical and health offices and clinics not exceeding 5,000 feet of floor area per office or group of offices;
- b. Planning;
- c. Engineering and architectural;
- d. Accounting;
- e. Auditing and bookkeeping;
- f. Educational and scientific.

Senior and/or Handicapped Housing or Senior Apartments: Age-restricted multi-unit housing for 55 and older adults, or handicapped persons, with self-contained living units for older adults who are able to care for themselves. Usually no additional services such as meals or transportation are provided.

Sit Down Restaurant: An eating establishment of high quality and with turnover rates generally of at least one hour or longer, serving food and beverages for retail sale, intended for consumption on the premises, and may include the sale and on-premises consumption of alcoholic beverages as an accessory use provided all necessary licenses are secured.

Treebelt: Can consist of tree planters, brick pavers, and benches with a minimum width of five feet.

3954. Use Regulations

39541. Special Permit Uses in a Mixed Use Development. Mixed use developments may be constructed in the Village Center (Receiving) District with the approval of a Special Permit with Site Plan Approval granted by the Planning Board. The following uses may be included within a mixed use development:

- a. Retail Uses;
- b. Sit Down Restaurants;
- c. Cafes and outdoor dining areas;
- d. Multi-family Residential uses;
- e. Home Occupations;
- f. Professional Service Offices;
- g. Personal Service Establishments;
- h. Municipal Uses;
- i. Banks or financial institutions;
- j. Health club;
- k. Hotel/Motel not exceeding 10 guest rooms per establishment;
- l. Bed-and-breakfast establishments;
- m. Townhouses (single family dwellings connected by one or more walls);
- n. Cinema, theatre, or auditorium;

- o. Park, recreation or playground;
- p. Artist studio/residence;
- q. Assisted living residential uses, senior apartments and senior housing;
- r. Artisan manufacturing or production (hand tools only, e.g. jewelry or ceramics);
- s. Civic uses;
- t. Live/work units;
- u. Multiple Uses in the same structure.

39542. Within a mixed use development, the following uses shall not be allowed as free standing buildings, and shall not provide drive through service windows:

- a. Fast food restaurants;
- b. High turnover sit-down restaurants;
- c. Banks.

39543. Prohibited Uses in a Mixed Use Development. The following uses shall not be included within a Mixed Use Development:

- a. Industrial uses;
- b. Motor vehicle sales, maintenance and repair facilities;
- c. Gasoline filling stations;
- d. Dry cleaning, linen cleaning, or diaper services which clean clothing articles on site.
- e. Adult entertainment uses;
- f. Animal hospitals, animal sales;
- g. Automobile or truck sales;
- h. Bars and cocktail lounges;
- i. Drive-up services associated with any commercial use;
- j. Junkyards.

3955. Same-structure/On-site Mixed Use

Within an approved Mixed Use Development or Mixed Use Infill development, there shall be no restriction on combining different categories of use within the same building except any imposed by the State Building Code or other federal, state, or local regulations.

3956. Special Permit Criteria for All Mixed Use Developments

39561. All Mixed Use Developments must meet the Special Permit with Site Plan Approval requirements in Section _____.

39562. All Mixed Use Developments must meet the following additional Special Permit criteria:

- a. The project complies with the additional performance standards specific to Mixed Use Developments in Section 3958 below.
- b. The project is consistent with the purposes of this Bylaws/Ordinance, as stated in Section 3951.

3957. Dimensional Requirements

The dimensional requirements applicable to the Mixed Use Overlay District are shown in the Table of Dimensional and Density Regulations below.

Table of Dimensional and Density Regulations for Mixed Use Development

Minimum Lot Area	Minimum Frontage	Minimum Front Yard	Minimum Side Yard	Minimum Rear Yard	Maximum Height	Maximum Lot Coverage
15,000 s.f.	120 feet	20 feet	10 feet	10 feet	50 feet/ 3 stories	85%

3958. Performance Standards for Mixed Use Developments

39581. Existing buildings shall be re-used for mixed use developments, where feasible, as a priority over new construction.

39583. New construction design shall be in harmony with the existing neighborhood or district.

39584. Buildings or structures that are listed or eligible for inclusion on the National Register of Historic Places and/or the Massachusetts Register of Historic Places or within a local historic district as established by M.G.L. Chapter 40C, shall be converted, constructed, reconstructed, restored or altered to maintain or promote the status of the building or structure on, or eligibility for inclusion on the State or National Register of Historic Places.

39585. Applicants shall consult the Deerfield Design Guidelines Handbook for guidance regarding design issues for mixed used development. Applicants shall indicate how the proposed development addresses the design issues referenced in the Deerfield Design Guidelines Handbook.

39586. Appearance/Architectural Design

- a. Architectural design shall be compatible with the historic character and scale of building in the neighborhood and the Town of Deerfield through the use of appropriate building materials, screening, breaks in roof and wall lines and other architectural techniques. Applicants should consult the Deerfield Design Guidelines Handbook for specific guidance on design issues.
- b. Variations in architectural detail, form and siting shall be used to provide visual interest and avoid monotony.
- c. Existing buildings subject to reconstruction or rehabilitation and proposed buildings shall be compatible with the historic character and scale of contiguous buildings within the immediate neighborhood vicinity.

- d. Proposed buildings should relate harmoniously to each other with adequate light, air, circulation, and separation between buildings.
- e. Buildings shall be designed so that only retail, restaurant, and personal service establishments shall be located on the ground or below grade building levels.
- f. The entire building façade must be oriented to front and side street property lines and must be located within ten feet of such property lines, with sidewalks in front of buildings.
- g. Public open spaces, such as plazas and pocket parks, are encouraged within the development.
- h. In making its decision, the Planning Board may consider whether the building design is compatible with the following design guidelines:
 - 1) exterior facades are faced with wood, metal, or vinyl clapboards, or stone or brick;
 - 2) exterior facade treatment is compatible on all four sides;
 - 3) rooflines are peaked;
 - 4) facades facing town streets have windows facing the street.

39587. Multi-family Housing Limits. Within a mixed use development, multi-family housing units may only be constructed on the second floor of a mixed use structure which has a business, personal or professional services use on the first floor. Senior and/or Handicapped Housing or Senior Apartments are allowed on the first floor to meet accessibility needs.

39587. Outdoor Dining

- a. Outdoor dining shall be permitted by right, as an accessory use for any restaurant use, and must comply with the following standards:
 - (1) Alcohol may be served to and consumed by patrons in outdoor dining areas, provided that all necessary licenses are acquired. These licenses are to be gathered through the Board of Selectmen, the Building Department and the Board of Health.
 - (2) The hours of operation of outdoor dining areas may be equal to or less than the hours of operation of the main restaurant. Dining areas which abut residential areas must end outdoor dining and seating by 11pm.
 - (3) Litter must be cleaned up regularly.

SECTION _____ DEERFIELD WETLANDS PROTECTION BYLAW

Draft dated 6-15-22

1. Purpose

The purpose of this bylaw is to protect the wetlands, water resources, flood prone areas, and adjoining upland areas (i.e. Buffer Zones) in the Town of Deerfield by controlling activities deemed by the Conservation Commission likely to have a significant or cumulative effect upon resource area values, including but not limited to the following:

- public or private water supply,
- groundwater,
- flood control,
- erosion and sedimentation control,
- storm damage prevention,
- water quality and water pollution control,
- wildlife habitat and rare species habitat including rare plant species,
- recreation values,
- carbon/greenhouse gas storage and sequestration,
- localized cooling,
- protection of biodiversity, and
- mitigation of impacts from climate change and adaptation to climate change .

This bylaw is intended to utilize the Home Rule authority of this municipality to protect additional resource areas, for additional values, with additional standards and procedures stricter than those of the Wetlands Protection Act (G.L. c. 131, § 40) and Regulations thereunder (310 CMR 10.00), subject, however, to the rights and benefits accorded to agricultural uses and structures of all kinds under the laws of the Commonwealth.

2. Definitions

Except as otherwise provided in this bylaw or in regulations of the Commission, the definitions of terms in this bylaw shall be as set forth in the Wetlands Protection Act (G.L. c. 131, § 40) and Regulations (310 CMR 10.00).

ALTER – To change the condition of any resource area subject to protection under this bylaw. Examples of alteration include but are not limited to, the following:

- 1) the changing of pre-existing drainage characteristics, flushing characteristics, sedimentation patterns, flow patterns and flood retention areas;
- 2) the raising or lowering of the water level or water table;

3) the destruction of vegetation;

4) the changing of water temperature, salinity, biochemical oxygen demand (BOD), and other physical, biological or chemical characteristics of the receiving water.

BANK – The land area which normally abuts and confines a water body; the lower boundary being the mean annual low flow level, and the upper boundary being the first observable break in the slope or the mean annual flood level, whichever is higher.

BUFFER ZONE – That area of land extending 150 feet horizontally outward from the boundary of a resource area, except that riverfront areas and vernal pools shall have no buffer zones.

ISOLATED VEGETATED WETLAND – A Freshwater Wetland, of at least 1,000 sf in areas that do not border creeks, rivers, streams, ponds, or lakes. The types of IVW may include wet meadows, marshes, swamps, and bogs. In addition to the minimum size requirement, IVW must also meet the definition and characteristics BVW stated in 310 Code Mass. Regs. 10.55(2) with the exception that IVW do not border any creeks, rivers, streams, ponds, lakes, or other water bodies.

ISOLATED LAND SUBJECT TO FLOODING – Land so defined in the Wetlands Protection Act and 310 CMR 10.57(2)(b) and they may be amended.

PERSON – Any individual, group of individuals, association, partnership, corporation, company, business organization, trust, estate, the Commonwealth or political subdivision thereof to the extent subject to town bylaws, administrative agency, public or quasi-public corporation or body, this municipality, and any other legal entity, its legal representatives, agents, or assigns.

POND – A water body as so defined in the Wetlands Protection Act and 310 CMR 10.04, except that a size threshold of 5,000 square feet shall apply.

RARE SPECIES – Without limitation, all vertebrate and invertebrate animal and plant species listed as endangered, threatened, or of special concern by the Massachusetts Division of Fisheries and Wildlife, regardless of whether the site in which they occur has been previously identified by the Division.

RESOURCE AREAS - Land under lakes, ponds, rivers or streams; any bank, marsh, wet meadow, bog or swamp bordering on any lake, pond, river or stream; land subject to flooding bordering on any lake, pond, river or stream; isolated land subject to flooding; isolated vegetated wetlands; riverfront areas; and vernal pools.

RESOURCE AREA VALUES – Without limitation, public or private water supply, groundwater, flood control, erosion and sedimentation control, storm damage prevention, water quality, water pollution control, wildlife habitat, rare species habitat including rare plant species, and recreation values.

RIVERFRONT AREA – Land as so defined in the Wetlands Protection Act and 310 CMR 10.58(2), as they may be amended.

STREAM – An open body of running water, including brooks and creeks, which moves in a definite channel, in the ground, due to a hydraulic gradient and flows within, into, or out of an Area Subject to Protection under this bylaw. Such bodies of running water that are intermittent are streams, except for those that serve only to carry the immediate surface runoff from stormwater or snowmelt. A portion of a stream may flow through a culvert or beneath a bridge. Where a stream or river runs thorough a

culvert more than 200 feet in length, the buffer zone or riverfront area stops at a perpendicular line at the upstream end of the culvert and resumes at the downstream end.

VERNAL POOL – A confined basin depression that, at least in most years, holds water for a minimum of two continuous months during the spring and/or summer, and that is free of adult fish populations, as well as the area within 100 feet of the mean annual boundary of such a depression, and that is breeding habitat for amphibian species such as wood frog, spotted salamander, and fairy shrimp, regardless of whether the site has been certified by the Massachusetts Division of Fisheries and Wildlife. A vernal pool does not have a buffer zone.

3. Jurisdiction

Except as permitted by the Conservation Commission or as provided in this bylaw, no person shall alter a resource area or a buffer zone. Resource areas shall be protected whether or not they border surface waters. Facilities constructed for the purpose of and designated as reservoirs shall be exempt from the jurisdiction of this bylaw.

Additional Jurisdictional Areas not covered by the Massachusetts Wetlands Protection Act that are included in this bylaw are:

- a. Isolated vegetated wetlands;
- b. Intermittent streams that are upgradient of Bordering Vegetated Wetlands;
- c. Ponds that meet the following definition: any open body of fresh water, either naturally occurring or man-made by impoundment or excavation, which is never without standing water due to natural causes, except in periods of extended drought. For purposes of this definition, extended drought shall mean any period of four or more months during which the average rainfall for each month is 50% or less of the ten-year average for that same month. Basins or lagoons which are part of wastewater treatment plants, swimming pools or other impervious man- made retention basins shall not be considered ponds.
- d. The preceding Resource Areas shall have 150-foot AURAs/Buffer Zones, known as the Adjacent Upland Resource Area or Buffer Zone.

4. Exemptions and Exceptions

The application and permit required by this bylaw shall not be required for the following activities:

- a. Maintaining, repairing, or replacing, but not substantially changing or enlarging an existing and lawfully located structure or facility used in the service of the public to provide electric, gas, water, telephone, telegraph, or other telecommunication services, provided that written notice has been given to the Commission prior to commencement of work, and provided that the work conforms to performance standards and design specifications in regulations adopted by the Commission;
- b. Work performed for normal maintenance or improvement of land which is lawfully in agricultural use;
- c. For emergency projects necessary for the protection of the health and safety of the public, provided that the work is to be performed by or has been ordered to be performed by an

agency of the Commonwealth or a political subdivision thereof; provided that advance notice, oral or written, has been given to the Commission prior to commencement of work or within 24 hours after commencement; provided that the Commission or its agent certifies the work as an emergency project; provided that the work is performed only for the time and place certified by the Commission for the limited purposes necessary to abate the emergency; and provided that within 21 days of commencement of an emergency project a permit application shall be filed with the Commission for review as provided by this bylaw. Upon failure to meet these and other requirements of the Commission, the Commission may, after notice and a public hearing, revoke or modify an emergency project approval and order restoration and mitigation measures.

- d. The application of herbicides as specifically set forth in 310 CMR 10.03(6) as may be amended.
- e. Facilities constructed for the purpose of and designated as reservoirs shall be exempt from the jurisdiction of this bylaw.
- f. Any bordering vegetated wetland, bank, land under water, land subject to flooding, or riverfront area created for the purpose of stormwater management shall not require the filing of a Notice of Intent or a Request for Determination of Applicability to maintain the stormwater management system, provided that the work is limited to the maintenance of the stormwater management system and that the area is not altered for other purposes.

Other than as stated in this section, the exceptions provided in the Wetlands Protection Act (G.L. c. 131, § 40) and Regulations (310 CMR 10.00) shall not apply under this bylaw.

5. Applications for Permits, Requests for Determination and Consultant Fee

- a. Written application shall be filed with the Commission to perform activities affecting resource areas protected by this bylaw. The permit application shall include such information and plans as are deemed necessary by the Commission to describe proposed activities and their effects on the resource areas protected by this bylaw. No activities shall commence without receiving and complying with a permit issued pursuant to this bylaw. Projects shall not be segmented.
- b. The Commission in an appropriate case may accept as the permit application and plans under this bylaw the Notice of Intent or the Request for Determination of Applicability filed under the Wetlands Protection Act (G.L. c.131, §40) and Regulations (310 CMR 10.00).
- c. Any person desiring to know whether or not a proposed activity or an area is subject to this bylaw may in writing request a determination from the Commission. Such a Request for Determination (RFD) shall include information and plans as are deemed necessary by the Commission. Such requirements shall be consistent with those required under the Wetlands Protection Act (G.L. c. 131, §40) and Regulations (310 CMR 10.00).
- d. The Commission may request an Applicant, submitting an application for a permit, the project cost of which is estimated at \$2,000,000 or more to retain and pay the fees for a Consultant to prepare a report for the Commission’s review. The project cost means the

estimated, entire cost of the project including but not limited to design, building construction, site preparation, landscaping, and all site improvements.

6. Notice and Hearings

- a. Any person filing a permit application or a RFD with the Commission shall at the same time give written notice thereof, by certified mail with return receipt requested, or hand delivered with signatures, to all abutters at their mailing addresses shown on the most recent applicable tax list of the assessors, including owners of land directly opposite on any public or private street or way, and abutters to the abutters within 100 feet of the property line of the applicant, including any in another municipality or across a body of water. The notice to abutters shall have enclosed a copy of the permit application or request, with plans, or shall state where copies may be examined and obtained by abutters. An affidavit of the person providing such notice, with a copy of the notice mailed or delivered, shall be filed with the Commission.
- b. When a person requesting a determination is other than the owner, the request, the notice of the hearing, and the determination itself shall be sent by the Commission to the owner as well as to the person making the request.
- c. The Commission shall conduct a public hearing on any permit application or RFD, with written notice given at the expense of the applicant, five business days prior to the hearing, in a newspaper of general circulation in the municipality.
- d. The Commission shall commence the public hearing within 21 days from receipt of a completed permit application or RFD unless an extension is authorized in writing by the applicant.
- e. The Commission shall issue its permit or determination in writing within 21 days of the close of the public hearing thereon unless an extension is authorized in writing by the applicant.
- f. The Commission in an appropriate case may combine its hearing under this bylaw with the hearing conducted under the Wetlands Protection Act (G.L. c.131, § 40) and Regulations (310 CMR 10.00).
- g. The Commission shall have authority to continue the hearing to a certain date announced at the hearing, for reasons stated at the hearing, which may include receipt of additional information from the applicant or others deemed necessary by the Commission in its discretion, or comments and recommendations of the boards and officials listed in §VII.

7. Coordination with Building Commissioner

Any person filing a permit application or RFD with the Commission shall provide written notification thereof at the same time to the building commissioner. An affidavit of the person providing notice, with a copy of the notice mailed or delivered, shall be filed with the Commission. The Commission shall not take final action until the Building Commissioner has had 14 days from receipt of notice to file written comments and recommendations with the Commission, which the Commission shall take into account but which shall not be binding on the Commission. The applicant shall have the right to receive any comments and recommendations, and to respond to them at a hearing of the Commission, prior to final action.

8. Permits and Conditions

- a. If the Commission, after a public hearing, determines that the activities which are subject to the permit application or the land and water uses which will result therefrom are likely to have a significant individual or cumulative effect upon the resource area values protected by this bylaw, the Commission, within 21 days of the close of the hearing, shall issue or deny a permit for the activities requested. If it issues a permit, the Commission shall impose conditions that the Commission deems necessary or desirable to protect those values, and all activities shall be done in accordance with those conditions. The Commission shall take into account the cumulative adverse effects of loss, degradation, isolation, and replication of protected resource areas throughout the community and the watershed, resulting from past activities, permitted and exempt, and foreseeable future activities.
- b. The Commission is empowered to deny a permit for failure to meet the requirements of this bylaw; for failure to submit necessary information and plans requested by the Commission; for failure to meet the design specifications, performance standards, and other requirements in regulations of the Commission; for failure to avoid or prevent unacceptable significant or cumulative effects upon the resource area values protected by this bylaw; and where no conditions are adequate to protect those values. Due consideration shall be given to any demonstrated hardship, financial or otherwise, on the applicant by reason of denial, as presented at the public hearing.
- c. Riverfront areas and buffer zones are presumed important to the protection of resource area values because activities undertaken in them have a high likelihood of adverse impact upon the wetlands or other resources, either immediately, as a consequence of construction, or over time, as a consequence of daily operation or existence of the activities. Such adverse impact from construction and use can include, without limitation, flooding, erosion, siltation, loss of groundwater recharge, poor water quality, and loss of wildlife habitat. The Commission therefore may require that the applicant maintain a strip up to 50 feet wide of continuous, undisturbed vegetative cover within a riverfront area or buffer zone.
- d. In the review of riverfront areas and buffer zones of streams, no permit issued hereunder shall permit any activities unless the applicant, in addition to meeting the otherwise applicable requirements of this bylaw, has proved by a preponderance of the evidence that (1) there is no practicable alternative to the proposed project with less adverse effects, and that (2) such activities, including proposed mitigation measures, will have no significant adverse impact on the areas or values protected by this bylaw. The Commission shall regard as practicable an alternative which is reasonably available and capable of being done after taking into consideration the proposed property use, overall project purpose (e.g., residential, institutional, commercial, or industrial purpose), logistics, existing technology, costs of the alternatives, and overall project costs.
- e. To prevent wetlands loss, the Commission shall require applicants to avoid wetlands alteration wherever feasible; shall minimize wetlands alteration; and, where alteration is unavoidable, shall require full mitigation. The Commission may authorize or require replication of wetlands as a form of mitigation, but only with adequate security, professional design, and monitoring to assure success, because of the high likelihood of failure of replication.
- f. A permit shall expire three years from the date of issuance. Notwithstanding the above, the Commission in its discretion may issue a permit expiring five years from the date of issuance for recurring or continuous maintenance work, provided that annual notification of time and location of work is given to the Commission. Any permit may be renewed once for an additional one year period, provided that a request for a renewal is received in writing by the Commission prior to expiration.

Notwithstanding the above, a permit may contain requirements which shall be enforceable for a stated number of years, indefinitely, or until permanent protection is in place, and shall apply to all owners of the land.

g. For good cause the Commission may revoke or modify a permit or determination issued under this bylaw after notice to the holder of the permit or determination, notice to the public, abutters, and town boards, pursuant to §VI and §VII, and a public hearing.

h. The Commission in an appropriate case may combine the permit or determination issued under this bylaw with the Order of Conditions or Determination of Applicability issued under the Wetlands Protection Act (G.L. c. 131, § 40) and Regulations (310 CMR 10.00).

i. No work proposed in any permit application shall be undertaken until the permit issued by the Commission with respect to such work has been recorded in the registry of deeds or, if the land affected is registered land, in the registry section of the land court for the district wherein the land lies, and until the holder of the permit certifies in writing to the Commission that the permit has been recorded.

9. Regulations

After public notice and public hearing, the Commission shall promulgate regulations to effectuate the purposes of this bylaw and shall be effective when voted and filed with the town clerk. Failure by the Commission to promulgate such regulations or a legal declaration of their invalidity by a court of law shall not act to suspend or invalidate the effect of this bylaw.

10. Security

As part of a permit issued under this bylaw, in addition to any security required by any other municipal or state board, agency, or official, the Commission may require that the performance and observance of the conditions imposed thereunder (including conditions requiring mitigation work) be secured wholly or in part by one or more of the methods described below:

- a. By a proper bond or deposit of money or negotiable securities or other undertaking of financial responsibility sufficient in the opinion of the Commission, to be released in whole or in part upon issuance of a Certificate of Compliance for work performed pursuant to the permit.
- b. By accepting a conservation restriction, easement, or other covenant enforceable in a court of law, executed and duly recorded by the owner of record, running with the land to the benefit of this municipality whereby the permit conditions shall be performed and observed before any lot may be conveyed other than by mortgage deed. This method shall be used only with the consent of the applicant.

11. Enforcement

- a. No person shall alter a resource area or a buffer zone, or cause, suffer, or allow alteration, or leave in place unauthorized fill, or otherwise fail to restore illegally altered land to its original condition, or fail to comply with a permit or an enforcement order issued pursuant to this bylaw.
- b. Only upon the filing of either an Request for Determination or a Permit under this bylaw the Commission, its agents, officers, and employees shall have authority to enter upon privately owned land for the purpose of performing their duties under this bylaw and may make or cause to be made such

examinations, surveys, or sampling as the Commission deems necessary, subject to the constitutions and laws of the United States and the Commonwealth. In the absence of the filing of a Request for Determination or a Permit the Commission, its agents, officers and employees shall consult with Town Counsel prior to entering upon privately owned land for the purpose of determining compliance with this by-law or for any other purpose in furtherance of the objectives of this by-law.

c. The Commission shall have authority to enforce this bylaw, its regulations, and permits issued thereunder by violation notices, administrative orders, and civil court actions. Any person who violates provisions of this bylaw may be ordered to restore the property to its original condition and take other action deemed necessary to remedy such violations, or may be fined, or both.

d. In the case of civil action, the Commission with the approval of the board of selectmen may request the town counsel to take legal action as necessary to enforce the terms of this by-law under civil law.

e. Municipal boards and officers, including any police officer or other officer having police powers, shall have authority to assist the Commission in enforcement.

f. Any person who violates any provision of this bylaw, or regulations, permits, or administrative orders issued thereunder, shall be punished by a fine of not more than \$300. Each day or portion thereof during which a violation continues, or unauthorized fill or other alteration remains in place, shall constitute a separate offense, and each provision of the bylaw, regulations, permits, or administrative orders violated shall constitute a separate offense.

g. As an alternative to criminal prosecution in a specific case, the Commission may issue citations under the non-criminal disposition procedure set forth in G.L. c. 40, § 21D, which has been adopted by the Town in Article 10.3 of the general bylaws.

12. Burden of Proof

The applicant for a permit shall have the burden of proving by a preponderance of credible evidence that the work proposed in the permit application will not have unacceptable, significant, or cumulative effect upon the resource area values protected by this bylaw. Failure to provide adequate evidence to the Commission supporting this burden shall be sufficient cause for the Commission to deny a permit or grant a permit with conditions.

13. Appeals

A decision of the Commission shall be reviewable in the Superior Court in accordance with G.L. c. 249, §4. This in no way alters or amends an applicant’s rights to appeal as set forth in the Massachusetts Wetlands Protection Act M. G.L. c.131 § 40.

14. Relation to the Wetlands Protection Act

This bylaw is adopted under the Home Rule Amendment of the Massachusetts Constitution and the Home Rule statutes, independent of the Wetlands Protection Act (G.L. c. 131, § 40) and Regulations (310 CMR 10.00) thereunder.

15. Severability

The invalidity of any section or provision of this bylaw shall not invalidate any other section or provision thereof, nor shall it invalidate any permit or determination that has been issued previously.

4350. FOREST PROTECTION OVERLAY DISTRICT

4350. Purposes

The purposes of this bylaw are:

- a. Insuring that any development that takes place within the Forest Protection Overlay District preserves and protects critical natural resource areas, minimizes visual impact of man-made features and enhances the economic values of the properties located therein;
- b. Minimizing the removal of native vegetation, especially large timber, and regulating the excavation and alteration of land in order to minimize any danger of erosion, flooding or pollution of the ground or surface water supply (public or private) within the district or any adjacent low lying areas;
- c. Protecting and maintaining healthy soils and their capacity for carbon sequestration.

4360. Scope of Authority

The Forest Protection Overlay District is an overlay district and shall be superimposed on the other districts established by this Bylaw. All regulations of the Deerfield Zoning Bylaw applicable to such underlying districts shall remain in effect, except that where the Scenic District imposes additional regulations, such regulations shall prevail.

4361. Designated Area. The Forest Protection Overlay District shall include all areas designated on the overlay map entitled Forest Protection Overlay District, Town of Deerfield, on file with the Town Clerk.

4362. The Forest Protection Overlay District is intended to include those mountain or upland areas which have one or more of the following characteristics:

- a. Steep slopes averaging 15% or greater for 200 feet.
- b. Any land at an elevation of 360 or more feet above sea level.

4370. Definitions

Clear Cutting: The cutting of all trees on a site.

Hillside: Land having an average grade of 15% or greater for 200 feet.

Ridgeline: The long, narrow crest or horizontal line of hills or mountains, usually at the highest elevation.

Selective Cutting: No more than 50% of the mature trees on a site cut under a selective cutting plan.

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- a. Insuring that any development that takes place within the Forest Protection Overlay District preserves and protects critical natural resource areas, minimizes visual impact of man-made features and enhances the economic values of the properties located therein;
- b. Minimizing the removal of native vegetation, especially large timber, and regulating the excavation and alteration of land in order to minimize any danger of erosion, flooding or pollution of the ground or surface water supply (public or private) within the district or any adjacent low lying areas;
- c. Protecting and maintaining healthy soils and their capacity for carbon sequestration.

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The Forest Protection Overlay District is an overlay district and shall be superimposed on the other districts established by this Bylaw. All regulations of the Deerfield Zoning Bylaw applicable to such underlying districts shall remain in effect, except that where the Scenic District imposes additional regulations, such regulations shall prevail.

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4350. Purposes

The purposes of this bylaw are:

- a. Insuring that any development that takes place within the Forest Protection Overlay District preserves and protects critical natural resource areas, minimizes visual impact of man-made features and enhances the economic values of the properties located therein;
- b. Minimizing the removal of native vegetation, especially large timber, and regulating the excavation and alteration of land in order to minimize any danger of erosion, flooding or pollution of the ground or surface water supply (public or private) within the district or any adjacent low lying areas;
- c. Protecting and maintaining healthy soils and their capacity for carbon sequestration.

4360. Scope of Authority

The Forest Protection Overlay District is an overlay district and shall be superimposed on the other districts established by this Bylaw. All regulations of the Deerfield Zoning Bylaw applicable to such underlying districts shall remain in effect, except that where the Scenic District imposes additional regulations, such regulations shall prevail.

4361. Designated Area. The Forest Protection Overlay District shall include all areas designated on the overlay map entitled Forest Protection Overlay District, Town of Deerfield, on file with the Town Clerk.

4362. The Forest Protection Overlay District is intended to include those mountain or upland areas which have one or more of the following characteristics:

- a. Steep slopes averaging 15% or greater for 200 feet.
- b. Any land at an elevation of 360 or more feet above sea level.

4370. Definitions

Clear Cutting: The cutting of all trees on a site.

Hillside: Land having an average grade of 15% or greater for 200 feet.

Ridgeline: The long, narrow crest or horizontal line of hills or mountains, usually at the highest elevation.

Selective Cutting: No more than 50% of the mature trees on a site cut under a selective cutting plan.

4350. FOREST PROTECTION OVERLAY DISTRICT

4350. Purposes

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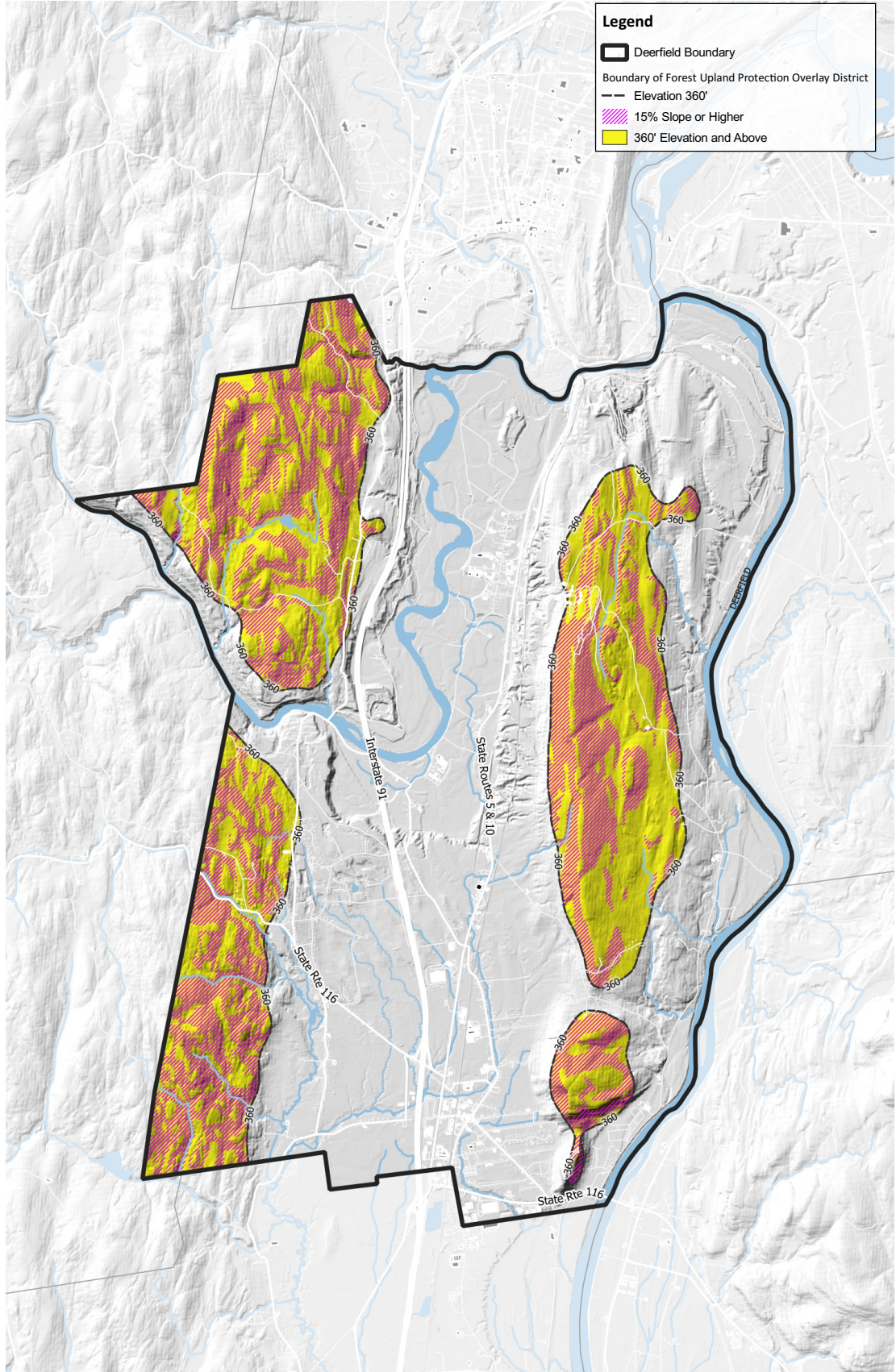
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4350. FOREST PROTECTION OVERLAY DISTRICT

4350. Purposes

Th



7000. SIGNIFICANT TREES

7010. Legislative findings and intent.

The Town of Deerfield finds that significant trees enhance air quality, reduce noise, reduce energy costs, create habitat, enhance aesthetics and property values, and benefit Town neighborhoods. The intent of this section is to encourage the preservation and protection of significant trees during development and redevelopment projects that require a site plan approval, special permit, comprehensive permit, finding, or variance (collectively "zoning relief").

7020. Definitions:

SIGNIFICANT TREES: Any tree of 20 inches diameter at breast height (DBH) or larger or any other tree specifically identified as a specimen tree on any Tree Inventory Plan adopted by the Planning Board.

7030. Removal of Significant Trees.

- A. No person shall remove any significant tree without a site plan approval from the Planning Board.
- B. The requirements of this section shall not apply to:
 - (1) Trees located on property under the jurisdiction of the Conservation Commission.
 - (2) Town-owned public shade trees pursuant to MGL Chapter 87.
 - (3) Trees associated with emergency projects necessary for public safety, health and welfare as determined by the Building Commissioner, Planning Board, or Director of Public Works.
 - (4) Trees that are hazardous due to disease, age, or shallow roots, as determined and confirmed in writing by a certified arborist and reviewed by the Planning Board.

7040. Conditions for Removal of Significant Trees.

Any person removing a significant tree that is subject to this section shall satisfy either of the following conditions:

- (1) Provide for replacement trees according to the following standards:
 - (a) Replacement trees shall be noninvasive deciduous or coniferous trees planted on or off site, as approved as part of a site plan, or on any town-owned property with approval by the Planning Board, unless such trees are public shade trees as per MGL c. 87, § 1.
 - (b) Replacements shall be calculated so that for each inch of diameter at breast height of the removed trees there shall be no less than 1/2 inch of caliper diameter of replacement trees.
 - (c) Replacement trees shall have a minimum of one-inch caliper diameter.
 - (d) Replacement trees shall be maintained in good health a minimum of 24 months after they are planted. If replacement trees are not found to be in "good health", the trees shall be replaced.
 - (d) Replacement trees shall either be approved street tree species or other trees that are hardy in all of the following USDA Plant Hardiness Zones: 6a, 6b, 7a, and 7b.

(2) Pay funds to the Town for a tree replacement fund account that, in the Planning Board's estimate, will allow the Town to plant new public shade trees on Town property in accordance with the above formula.

7050. Protection of Significant Trees during Construction.

(1) Any significant trees to be retained and any replacement trees on property where demolition and/or construction activity is planned shall be protected in an area shown on the approved site plan and should follow American National Standards Institute (ANSI) A300 standards for tree care practices.

(2) The protected area shall exceed both the critical root zone and drip-line of each significant tree unless the Planning Board approves an alternate maintenance and tree protection plan submitted by a certified arborist.

(3) A certified arborist shall submit a written letter to the Building Commissioner, and Planning Board certifying that such area has been so protected in accordance with the site plan.

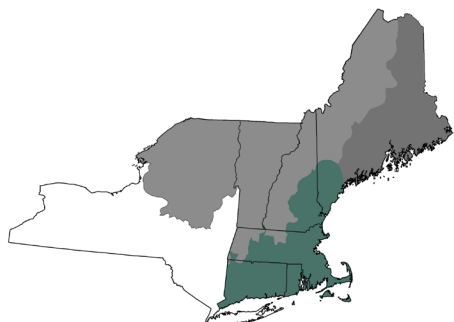
APPENDIX 2: SOIL ORGANIC CARBON ESTIMATION PROCESS

Estimated current Soil Organic Carbon was calculated by adjusting the SSURGO 1 meter depth SOC to account for the land cover of the typical pedon of the dominant soil type in each mapunit. This assumes that for upland soil map units, forest cover has the greatest average SOC concentration (98.2 t/ac). Therefore, in a Paxton soil, where the typical pedon is from a shrubland, we adjusted upward by the average SOC difference measured between shrubland (47.2 t/ac) and forest. The adjustment percentages were calculated by the Healthy Soils Action Plan team using the NRCS's Rapid Carbon Assessment data.

The Pedon adjusted SSURGO map units were then intersected with the 2016 high resolution land cover and a SOC value was calculated for each land cover SSURGO mapunit combination to account for the impact the current land cover would be expected to have on the SOC values.

Resulting in a final estimated current SOC value. Depending on the land use history, including farming practices, of a particular area the actual SOC may be very different.

CLIMATE CHANGE PROJECTIONS FOR INDIVIDUAL TREE SPECIES
SOUTHERN AND COASTAL NEW ENGLAND



This region's forests will be affected by a changing climate and other stressors during this century. A team of managers and researchers created an assessment that describes the vulnerability of forests in the region ([Janowiak et al. 2018](#)). This report includes information on observed and future climate trends, and also summarizes key vulnerabilities

for forested natural communities. The Landscape Change Research Group recently updated the Climate Change Tree Atlas, and this handout summarizes that information. Full Tree Atlas results are available online at www.fs.fed.us/nrs/atlas/. Two climate scenarios are presented to "bracket" a range of possible futures. These future climate projections (2070 to 2099) provide information about how individual tree species may respond to a changing climate. Results for "low" and "high" emissions scenarios can be compared on the reverse side of this handout.

The updated Tree Atlas presents additional information helpful to interpret tree species changes:

- Suitable habitat - calculated based on 39 variables that explain where optimum conditions exist for a species, including soils, landforms, and climate variables.
- Adaptability - based on life-history traits that might increase or decrease tolerance of expected changes, such as the ability to withstand different forms of disturbance.
- Capability - a rating of the species' ability to cope or persist with climate change in this region based on suitable habitat change (statistical modeling), adaptability (literature review and expert opinion), and abundance (FIA data). The capability rating is modified by abundance information; ratings are downgraded for rare species and upgraded for abundant species.
- Migration Potential Model - when combined with habitat suitability, an estimate of a species' colonization likelihood for new habitats. This rating can be helpful for assisted migration or focused management (see the table section: "New Habitat with Migration Potential").

Remember that models are just tools, and they're not perfect. Model projections can't account for all factors that influence future species success. If a species is rare or confined to a small area, model results may be less reliable. These factors, and others, could cause a particular species to perform better or worse than a model projects. Human choices will also continue to influence forest distribution, especially for tree species that are projected to increase. Planting programs may assist the movement of future-adapted species, but this will depend on management decisions. Despite these limits, models provide useful information about future expectations. It's perhaps best to think of these projections as indicators of possibility and potential change.

SOURCE: This handout summarizes the full model results for the Southern and Coastal New England region, available at www.fs.fed.us/nrs/atlas/combined/resources/summaries. More information on vulnerability and adaptation in the New England region can be found at www.forestadaptation.org/new-england. A full description of the models and variables are provided in Iverson et al. 2019 (www.nrs.fs.fed.us/pubs/57857) and www.nrs.fs.fed.us/pubs/59105) and Peters et al. 2019 (www.nrs.fs.fed.us/pubs/58353).

CLIMATE CHANGE CAPABILITY

POOR CAPABILITY

American basswood	Paper birch
Balsam fir	Pitch pine
Balsam poplar	Red pine
Black ash	Red spruce
Black spruce	Slippery elm
Black walnut	Striped maple
Bur oak	Swamp white oak
Eastern white pine	Sweet birch
Hackberry	Tamarack (native)
Northern pin oak	White spruce

Northern white-cedar

FAIR CAPABILITY

Black locust	White ash
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Quaking aspen

GOOD CAPABILITY

American beech	Post oak
American holly	Red maple
Black cherry	Sassafras
Black oak	Scarlet oak
Blackgum	Shagbark hickory
Chestnut oak	Sugar maple
Eastern redcedar	Sweetgum
Mockernut hickory	White oak
Northern red oak	Yellow-poplar

Pignut hickory

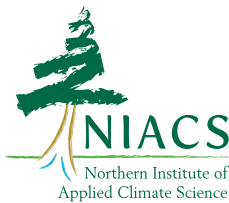
MIXED RESULTS

American elm	Gray birch
American hornbeam	Green ash
Bigtooth aspen	Ironwood
Eastern hemlock	Silver maple
Flowering dogwood	Yellow birch

NEW HABITAT WITH MIGRATION POTENTIAL

Chinkapin oak	Sweetbay
Loblolly pine	Virginia pine
Shortleaf pine	Water hickory

Southern red oak



www.forestadaptation.org

ADAPTABILITY: Life-history factors, such as the ability to respond favorably to disturbance, that are not included in the Tree Atlas model and may make a species more or less able to adapt to future stressors.

- + **HIGH** *Species may perform better than modeled*
- **MEDIUM**
- **LOW** *Species may perform worse than modeled*

HABITAT CHANGE: Projected change in suitable habitat between current and potential future conditions.

INCREASE *Projected increase of >20% by 2100*

NO CHANGE *Projected change of <20% by 2100*

DECREASE *Projected decrease of >20% by 2100*

NEW HABITAT *Tree Atlas projects new habitat for species not currently present*

SPECIES	LOW CLIMATE CHANGE (RCP 4.5)				HIGH CLIMATE CHANGE (RCP 8.5)			
	HABITAT		HABITAT		HABITAT		HABITAT	
	ADAPT	ABUN	CHANGE	CAPABILITY	CHANGE	CAPABILITY	CHANGE	CAPABILITY
American basswood	•	–						
American beech	•	•						
American elm	•	•						
American holly	•	–						
American hornbeam*	•	–						
American mountain-ash*	–	–						
Atlantic white-cedar*	–	–						
Bald cypress	•	–						
Balsam fir	–	•						
Balsam poplar	•	–						
Bigtooth aspen	•	•						
Bitternut hickory*	+	–						
Black ash	–	–						
Black cherry	–	•						
Black locust*	•	–						
Black oak	•	•						
Black spruce	•	–						
Black walnut*	•	–						
Blackgum	+	–						
Boxelder*	+	–						
Bur oak	+	–						
Chestnut oak	+	–						
Chinkapin oak	•	–						
Eastern hemlock	–	+						
Eastern redcedar	•	•						
Eastern white pine	–	+						
Flowering dogwood	•	–						
Gray birch*	•	–						
Green ash*	•	–						
Hackberry	+	–						
Honeylocust*	+	–						
Ironwood*	+	–						
Loblolly pine	•	–						
Longleaf pine	•	–						
Mockernut hickory	+	–						
Northern pin oak	+	–						

ABUNDANCE: Based on Forest Inventory Analysis (FIA) summed Importance Value data, calibrated to a standard geographic area.

- + **ABUNDANT**
- **COMMON**
- **RARE**

CAPABILITY: An overall rating that describes a species’ ability to cope or persist with climate change based on suitable habitat change class (statistical modeling), adaptability (literature review and expert opinion), and abundance within this region.

GOOD *Increasing suitable habitat, medium or high adaptability, and common or abundant*

FAIR *Mixed combinations, such as a rare species with increasing suitable habitat and medium adaptability*

POOR *Decreasing suitable habitat, medium or low adaptability, and uncommon or rare*

SPECIES	LOW CLIMATE CHANGE (RCP 4.5)				HIGH CLIMATE CHANGE (RCP 8.5)			
	HABITAT		HABITAT		HABITAT		HABITAT	
	ADAPT	ABUN	CHANGE	CAPABILITY	CHANGE	CAPABILITY	CHANGE	CAPABILITY
Northern red oak	+	+						
Northern white-cedar	•	–						
Paper birch	•	•						
Pignut hickory	•	•						
Pin cherry*	•	–						
Pin oak*	–	–						
Pitch pine	•	•						
Post oak	+	–						
Quaking aspen	•	•						
Red maple	+	+						
Red pine	–	–						
Red spruce	–	–						
Sassafras*	•	–						
Scarlet oak	•	•						
Shagbark hickory	•	•						
Shortleaf pine	•	–						
Silver maple*	+	–						
Slippery elm*	•	–						
Southern red oak	+	–						
Striped maple	•	–						
Sugar maple	+	•						
Swamp chestnut oak*	•	–						
Swamp tupelo	–	–						
Swamp white oak*	•	–						
Sweet birch	–	•						
Sweetbay	•	–						
Sweetgum	•	–						
Sycamore*	•	–						
Tamarack (native)	–	–						
Virginia pine	•	–						
Water hickory	•	–						
White ash	–	•						
White oak	+	•						
White spruce	•	–						
Yellow birch	•	•						
Yellow-poplar	+	–						

*Species with low model reliability based on five statistical metrics of the habitat models that affect change class. See maps and tables for more information (www.fs.fed.us/nrs/atlas/combined/resources/summaries).

APPENDIX 4: PREDOMINANT SOIL FUNCTIONS FOR RESILIENCE FOR EACH PROJECT SITE

TOWN	SITE	PREDOMINANT SOIL FUNCTIONS FOR RESILIENCE			
		Highly Degraded	High Regeneration Potential	Moderate-Low Function	High Function
Ashburnham	Phillips Brook/Residential Area on Main St.	◆	◆		◆
Ashburnham	Pump Station			◆	
Ashburnham	Sweeney Park	◆	◆		
Ashburnham	Dump/Transfer Station			◆	
Ashburnham	Page Ave		◆		
Ashburnham	High St./Cushing St.	◆	◆		
Ashburnham	S. Branch Souhegan River		◆		◆
Ashburnham	Brickford Field			◆	◆
Fitchburg	Cleghorn St.			◆	
Fitchburg	Civic Center/Falulah Brook			◆	
Fitchburg	Coolidge Park			◆	
Fitchburg	Green Acres		◆		
Fitchburg	Putt’s Pond			◆	◆
Fitchburg	Greene’s Pond			◆	◆
Fitchburg	Parkhill Park/Sand Brook			◆	
Fitchburg	Beekman St. and Hobson St. Culverts	◆		◆	
Fitchburg	Longsjo School			◆	
Groton	Broad Meadow		◆	◆	
Groton	Groton Country Club	◆	◆	◆	
Groton	Nod Road			◆	
Groton	Middle School Parking	◆			
Groton	Cow Pond Brook/Playing Fields			◆	
Groton	Willowdale		◆	◆	◆
Groton	James Brook				◆
Groton	Groton Town Hall	◆			
Leominster	Barrett Park			◆	◆
Leominster	Fournier Ballfields			◆	
Leominster	Mechanic St.			◆	
Leominster	Mall Area			◆	
Leominster	Johnny Appleseed SP (DCR)		◆		◆
Pepperell	Bemis Wellhead Protection Zone/Gulf Brook		◆	◆	◆
Pepperell	Heald Orchard/Heald Pond		◆		◆
Pepperell	Unkety Brook		◆	◆	◆
Pepperell	Fitzpatrick School Parking	◆	◆		
Pepperell	Railroad Square	◆	◆		
Pepperell	Mill Street/Varnum Brook			◆	
Pepperell	Reedy Meadow off Lowell Rd.		◆	◆	◆

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otherwise noted.
Draft Revised: June 6, 2024