Inland Interventions for Coastal Resilience in Mystic, Connecticut

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Winter 2019

Prepared for the Town of Stonington
with funding provided by the Community
Foundation of Eastern Connecticut via a grant
to The Nature Conservancy

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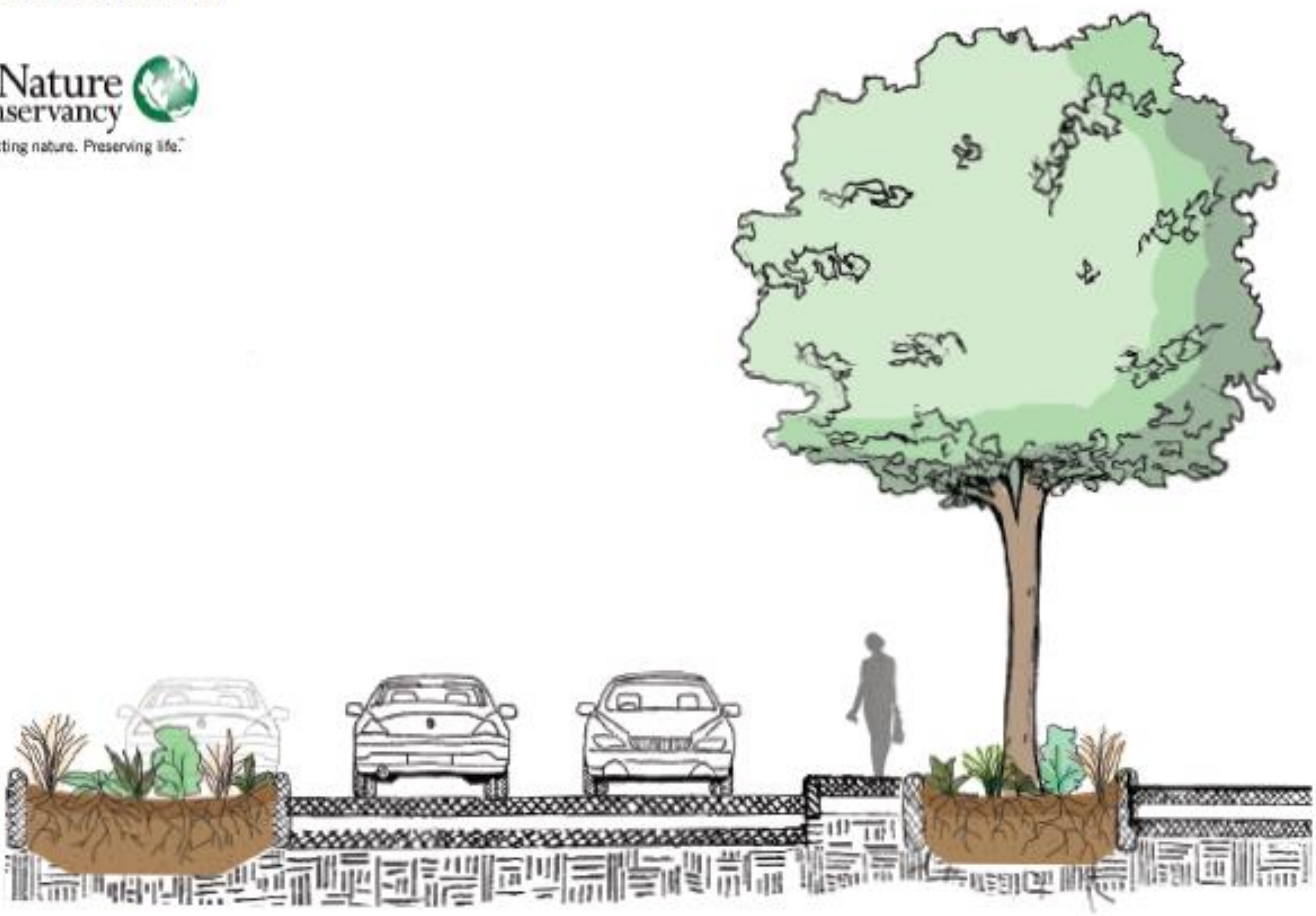


Funding for this report was provided by the Community Foundation of Eastern Connecticut through a grant to The Nature Conservancy's Community Resilience Building Program.

We would like to thank Keith Brynes and Scot Deledda from the Town of Stonington, and Adam Whelchel and Cary White from The Nature Conservancy, for the opportunity to work on behalf of the community in Mystic. We would also like to extend a special thank you to residents of Stonington and Groton for their valuable insight and feedback that helped shape this plan.

Contents

Downtown Mystic experiences a water sandwich effect; pressures of inundation from sea level rise and stormwater runoff from impervious surfaces and higher elevations cause water to accumulate in the low-lying downtown area.

Project Overview

This report, *Inland Interventions for Coastal Resilience,* is paired with *Shoreline Interventions for Coastal Resilience.* Together these reports provide a comprehensive view of coastal climate resilience in the village of Mystic through analysis and proposed interventions that address the impacts of sea level rise, storm surge, and increased precipitation as a result of climate change.

Mystic is a historic village located along the southeastern coast of Connecticut. The village lies at an estuary, straddling both sides of the Mystic River where it meets the Mystic Harbor. The village extends across portions of the towns of Groton and Stonington.

The name Mystic derives from the Pequot term missi-tuk, a large river whose waters are driven into waves by tides and winds. The Pequot native people established villages along the Mystic River centuries ago and since then, the area has undergone numerous settlements.

Throughout the eighteenth and nineteenth centuries, Mystic was an active seaport with a strong economy based on agriculture, manufacturing, and ship building (Connecticut Trust for Historic Preservation). The Mystic Bridge was built in 1819, connecting the east and west sides of the Mystic River (Mystic River Historical Society). Mystic Village developed into New England's primary port for sealing, whaling, and trade; the harbor drew in merchant vessels and sailors from around the world (Mystic River Historical Society). The vibrant economy required extensive development of the coastline to accommodate the visiting ships and sailors. The booming economy allowed for prosperous residents to build structures in Greek Revival and Queen Anne fashion, the most popular architectural styles of the nineteenth century. The narrow streets of downtown, connected by small through-streets that lead to the water, are reminders of this historical building period. Mystic's history as a seaport hub remains visible in its intact historic districts, museums, and cultural events. Mystic attracts a large tourist crowd in the summer months, drawn to the area for its unique intact historic village and its boat access.

Centuries of development around the water have resulted in a hardened shoreline, dominated by structures like bridges, piers, docks, and marinas. Shoreline hardening allows human development to come up to the edge of water and land and provides boat access to the water. The coastal area of Mystic is defined by human interventions for business and boating; few natural open areas remain. Land use in Mystic is primarily residential; it is home to approximately 4,000 year-round residents. Today, Mystic Village seeks to balance its historic resources and water access with the anticipated effects of climate change on the coastal community.

The Northeast United States is experiencing an increase in the intensity and frequency of storm events as a result of climate change (USGCRP). The quantity of rain that falls during heavy rain events (defined as the heaviest 1% of all daily events) increased by 71% between 1958 and 2012 (USGCRP 2014). The Northeast is also experiencing the global trend of sea level rise. Rising sea levels will exacerbate the impacts of storm surge, flooding, and erosion on coastal communities (USGCRP).

Floods in Mystic are increasing in intensity and frequency. The village of Mystic has a long history of impact from hurricanes and other storm events. Most recently, the direct path of Superstorm Sandy missed Mystic, yet the area still experienced significant flooding and related storm damages. In recognition of climate change and increased stressors on coastal communities, the Town of Stonington commissioned a coastal resilience plan, published in August 2017.

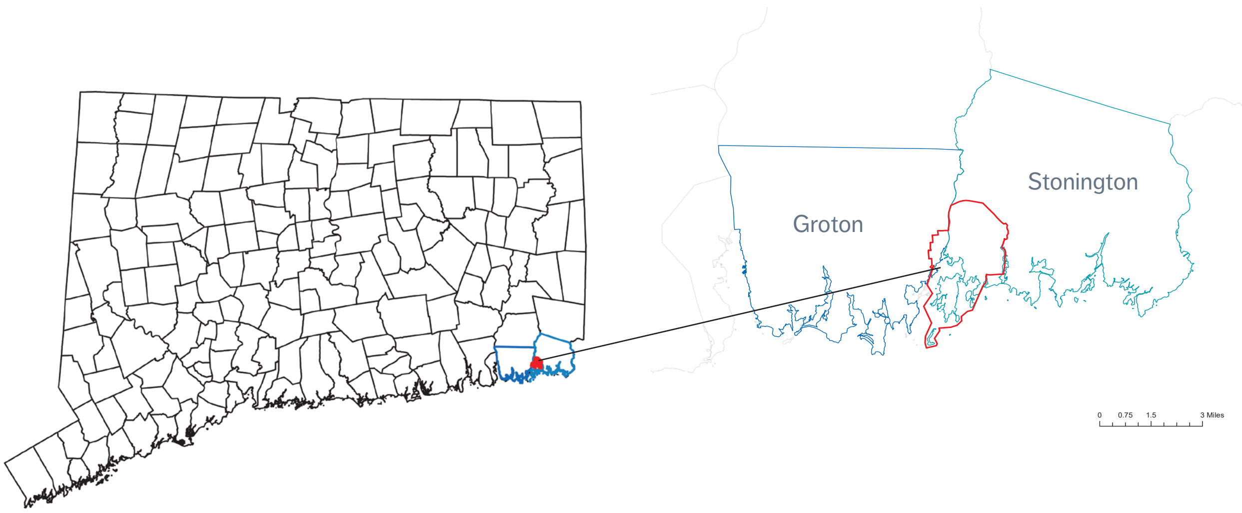
The *Coastal Resilience Plan* employed a three-step approach to address coastal resilience. It established a climate baseline by modelling sea level rise and storm surge on the land. It identified areas at risk within Stonington by factoring degrees of hazard, exposure, and vulnerability. Finally, it developed a broad outline of resilience strategies and next steps. The *Coastal Resilience Plan* is an invaluable resource for the Town of Stonington and its residents. The research and analysis in the *Coastal Resilience Plan* forms the basis for this report.

The *Coastal Resilience Plan* identified Mystic as an area at high risk given its geophysical characteristics, including its low elevation and exposure to the water, and its wealth of historic and cultural resources. Mason's Island, a residential barrier island connected to Mystic by a causeway, was also identified as an area at high risk.

In 2019, the Town of Stonington commissioned two reports, *Shoreline Interventions for Coastal Resilience* and *Inland Interventions for Coastal Resilience*, as the next steps in the design process of interventions for climate adaptation and mitigation. These reports identify suitable sites for interventions and present illustrative renderings for a defined project area that includes the Stonington and Groton sides of Mystic, and Mason's Island. *Shoreline Interventions for Coastal Resilience* focuses on living shorelines as a strategy to adapt to and mitigate sea level rise and storm surge inundation. *Inland Interventions for Coastal Resilience* focuses on green infrastructure as a strategy to manage stormwater, in response to the trend of increasing precipitation as a result of climate change.

The two reports work independently of each other but can be used in concert to provide a comprehensive view of coastal climate resilience.

The reports include proposed interventions that are site-specific to Mystic Village, Stonington. Yet, the intention is that these recommendations can be modified for application in similar historic communities along the Atlantic coast. Mystic Village has the opportunity to minimize damage to its historic built environment and provision for the effects of climate change, and, in doing so, become a model for other coastal communities.



Executive Summary

In 2017, the town of Stonington commissioned a *Coastal Resilience Plan* to help the community plan for future impacts of climate change. The plan identified green infrastructure as an approach to adapting to increased intensity and frequency of storm events and mitigating the impacts of stormwater.

Green infrastructure is an approach to managing stormwater by treating it close to its source while delivering environmental, social, and economic benefits. This is largely done by replacing impervious surfaces with vegetation and well-draining soils that slow, spread, and filter otherwise untreated runoff. Green infrastructure decreases the amount of water entering the municipal stormwater system, which can relieve pressure during heavy precipitation events, consequently reducing the likelihood of damage to existing infrastructure and the cost of repair. Additionally, the quality of stormwater entering water bodies and the water table improves when stormwater is intercepted by a tree canopy, absorbed through roots, and/or filtered through soil or permeable surfaces. These processes remove pollutants and cool stormwater.

In contrast to green infrastructure, Mystic's stormwater is currently managed in a separate storm sewer system that collects only stormwater runoff from impervious surfaces via catch basins and discharges it untreated into surrounding water bodies. In heavy precipitation events, large volumes of water move from higher elevations and collect in low-lying areas causing localized flooding. Additionally, during storm surges or especially high tides, water from the Mystic River and Mystic Harbor enters the storm sewer system outfalls which are concentrated along the coast and backflows through the storm pipes and out the catchment basins into the streets. These conditions can result in both large and small floods that pose a significant risk to Mystic's historic and cultural assets, tourist activity, and day-to-day quality of life. Stormwater carries pollutants directly into Mystic River, Mystic Harbor, and the Pequotsepos River, which can result in these water bodies becoming impaired.

As the climate continues to change, the negative impacts of stormwater will only intensify.
This report aims to address these challenges through conceptual green infrastructure designs and guidelines that respond to the particular conditions in Mystic. General green infrastructure parameters are included that help identify optimal site conditions and guide implementation. Strategies are divided into the three categories of non-residential, residential, and green streets. Recommendations were created based on an analysis of the existing stormwater conditions in Mystic, with a focus on impervious surfaces, drainage patterns, and habitat. This report is intended to serve as a catalyst for future detailed site design projects, both in Mystic and in similar coastal communities. Next steps are highlighted, including outreach and education, identifying funding sources, and conducting detailed site analysis where green infrastructure strategies are proposed.

Introduction


Photo by: Peasap

MITIGATION, ADAPTATION, AND RESILIENCE

Three broad responses to the threats posed by climate change include mitigation, adaptation, and resilience. These are different though related concepts, and the recommendations in this report incorporate aspects of all three.

Mitigation
The Federal Emergency Management Agency (FEMA) defines mitigation as the actions that we can take now to reduce loss of life and property in the future. These actions lessen the impact of disasters by assessing risk and investing in long-term community well-being. In order to prevent repeated damage from disasters, FEMA works on several mitigation efforts including risk analysis, risk reduction, and risk insurance.

Risk assessment involves analysis of existing conditions and threats, and implementation of strategies such as modifying infrastructure or changing behavior. In Mystic, strategies could include redirecting runoff into detention areas or softening shorelines to reduce impacts of storm surge. Mitigation can take place on various scales, from personal actions to government programs. Stormwater pollution mitigation can be achieved by eliminating the use of fertilizers, herbicides, and pesticides. Homeowners can also employ a variety of residential green infrastructure interventions for stormwater management on site.

Adaptation
Climate change adaptation involves planning ahead by assessing vulnerability to regional climate change related hazards and making significant changes to existing conditions. Adaptation involves anticipatory changes in land use, transportation systems, energy systems, water systems, and the built environment. Anticipating and planing for change requires evaluation and assessment, followed by planning that accommodates the needs of human development, wildlife habitats, and ecological functions given the challenges of increasing climate stressors. Creative strategies for adaptation emerge from these analyses. Adaptation and mitigation measures must be implemented together to reduce the current and future impacts of climate change.

Resilience
While resilience is often measured in terms of the engineering concept of resisting disturbance or bouncing back to “normal,” it can be redefined from an ecological perspective to mean the ability of systems to continually adapt to future challenges (Davoudi). Once initial mitigation and adaptation strategies are in place throughout Mystic, ecological resilience may include revising and expanding green infrastructure strategies over time, both for inland stormwater interventions and shoreline interventions for storm surge. With sea level rise and storm surge threatening Mystic, ecological resilience may also involve managed relocation from the coasts.

CLIMATE CHANGE IMPACTS IN CONNECTICUT

Climate change is happening primarily as a result of human activities. The global concentration of CO_2 in the atmosphere has surpassed 400 parts per million, which is the highest it's been in the past 3 million years (Governors Council on Climate Change i). This is causing temperatures and sea levels to rise, increasing the intensity and frequency of storms, and damaging ecosystems and communities.

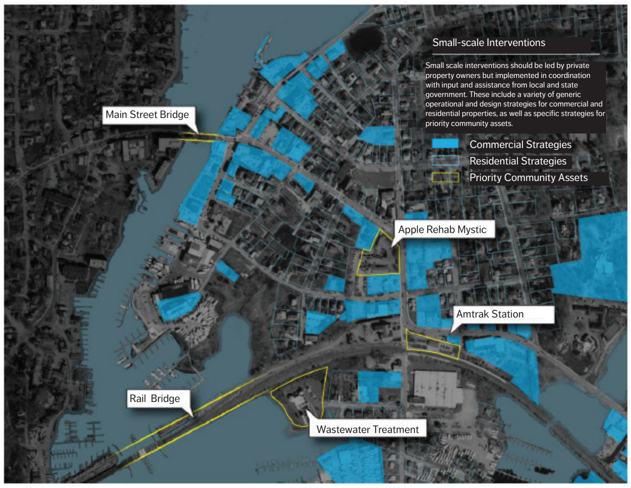
Connecticut is especially vulnerable to the impacts of climate change because of its geophysical features and location along the coastline. The Nature Conservancy estimates that the state will lose 24,000 acres of land to sea-level rise by 2080 (Ofgang et al.). Additionally, coastal land is gradually sinking. This has resulted in sea levels rising at much faster rates in the Northeast than the national average (Ofgang et al.). Furthermore, over the last century, New England's total annual precipitation has increased, and warmer temperatures are resulting in less snow and more rain during winter months, leading to flooding year-round (Bradley et al. 12). The combination of sea level rise, increased precipitation, and higher temperatures threatens coastal communities in Connecticut.

For example, in 2012, Superstorm Sandy caused substantial damage in Connecticut. Some residents were forced to evacuate and others experienced power outages and property damage. In total, the storm caused $2 billion in damage (Governors Council on Climate Change ii). It is predicted that as the climate continues to warm, the frequency and severity of storm events like Sandy will intensify, impacting coastal communities like Mystic.

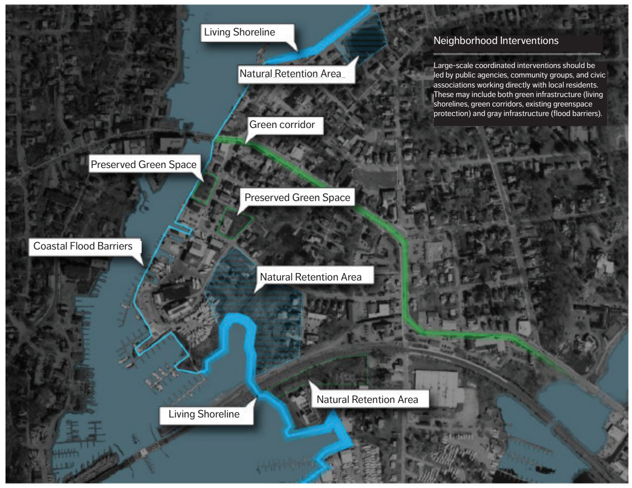
In response to the growing threat of climate change, in 2008 the Connecticut State Legislature passed the Global Warming Solutions Act, which aimed to reduce greenhouse gas emissions by 10% below 1990 levels by 2020, and 80% below 2001 levels by 2050 (Governors Council on Climate Change ii). Additionally, the state joined in a cooperative effort with Delaware, Maine, Maryland, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont to cap and reduce CO_2 emissions from the power sector through The Regional Greenhouse Gas Initiative (Governors Council on Climate Change 6). In line with the state's actions to address climate change, the town of Stonington is also taking steps towards climate resilience. Residents have formed numerous groups, including the Climate Change Task Force, a group of concerned citizens that work on various climate change initiatives within the town, and Clean Up Sound and Harbors (CUSH), a group focused on educating residents about how to improve water quality and foster environmental stewardship. In 2017 the Town of Stonington commissioned a *Coastal Resilience Plan* to help the community plan for future climate-related events.

Flooding from an extremely high tide coupled with heavy precipitation on Washington Street.
(Photos by Scot Deledda. March 2, 2018)

COASTAL RESILIENCE PLAN: INLAND STRATEGIES



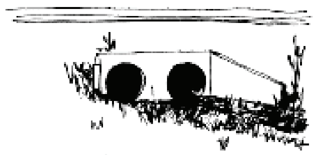
Proposed small-scale interventions from the 2017 *Coastal Resilience Plan* (Town of Stonington et al. 57)



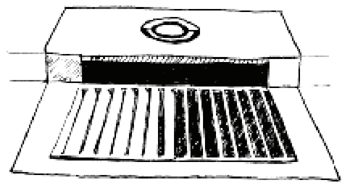
Proposed neighborhood interventions from the 2017 *Coastal Resilience Plan* (Town of Stonington et al. 57)

By identifying areas of high risk, engaging the public, and proposing broad solutions for climate adaptation, the 2017 *Coastal Resilience Plan (CRP)* (Town of Stonington et al.) helped the town of Stonington take the first step towards implementing strategies for climate resilience. It presented recommendations for neighborhood and small-scale interventions. Neighborhood interventions include larger-scale coordinated strategies led by public agencies, community groups, and civic associations. Examples in the CRP include installing a “green corridor” along Route 1, raising roads, creating natural retention areas along the coast, and preserving existing green space. Small-scale strategies are those led by private property owners, but implemented in coordination with input and assistance from the local and state government. Examples in the plan include wet floodproofing homes, filling in basements, and elevating structures and electrical equipment. Additionally, green infrastructure was recommended at both the neighborhood and smaller scale because of its low cost compared to other strategies, limited regulatory constraints, and ability to provide other social, economic, and environmental benefits.

GRAY INFRASTRUCTURE VS. GREEN INFRASTRUCTURE



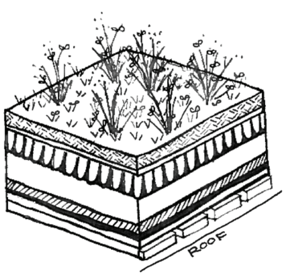
Culvert



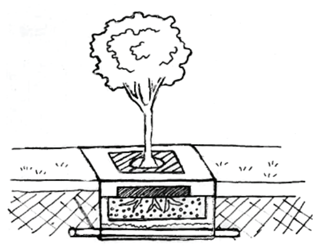
Catchment basin/
storm drain

GRAY INFRASTRUCTURE

Stormwater runoff is water from rain, snow melt, and other precipitation events that runs off impervious surfaces—surfaces that offer no infiltration. These can include roofs, parking lots, streets, and compacted soil. Most cities and towns manage stormwater using gray infrastructure, an engineered system of pipes and basins designed to quickly move water away from the built environment. A typical gray infrastructure system collects water from impervious surfaces via catchment basins and storm pipes, and discharges it into water bodies via outfalls. In heavy rain events, large volumes of runoff can stress and overwhelm gray infrastructure systems, causing floods and resulting in damage to pipes and culverts. Also, these systems offer no water quality treatment.



Green roof



Treebox filter

GREEN INFRASTRUCTURE

In contrast, green infrastructure is an approach to managing stormwater by treating it close to its source while delivering environmental, social, and economic benefits. This is largely done by directing runoff from impervious surfaces into areas planted with vegetation growing in soils that slow, sink, and filter otherwise untreated runoff. Green infrastructure decreases the amount of water entering the municipal stormwater system, which can relieve pressure during large precipitation events, consequently reducing the likelihood of damage to existing infrastructure and the cost of repair. Additionally, the quality of stormwater entering the water table improves when stormwater is intercepted by a tree canopy, absorbed through roots, and/or filtered through soil, because pollutants are removed and the temperature of stormwater decreases. Green infrastructure strategies can be implemented on small and large scales, from residential rain gardens to floodable parks. Porous pavements and rainwater collection for reuse via cisterns are often considered along with green infrastructure techniques that incorporate plants.

Curb-cuts funnel runoff to bioswales
Photo credit: Chris Hamby

Curb-cuts direct runoff to street trees
Photo credit: Chris Hamby

Vegetated medians intercept stormwater and shade streets.
Photo credit: Chris Hamby

In addition to reducing flooding and improving water quality, green infrastructure can:

- Increase water availability:
  Rainwater captured in rain barrels or cisterns can be used for irrigation, thus decreasing the demand for potable municipal water (U.S. EPA 2015a).
- Reduce the heat island effect:
  Trees help reduce ambient temperatures by shading areas underneath and through the process of evapotranspiration (U.S. EPA 2018a)
- Improve air quality:
  Vegetation helps decrease ambient temperatures, consequently reducing air pollution caused by smog, which is exacerbated by higher temperatures. Additionally, harmful particulates are intercepted by leaves and bark (U.S. EPA 2015a). One study in Philadelphia found that increasing tree canopy could improve air quality enough to significantly reduce mortality, hospital admissions, and work loss days (U.S. EPA 2015a).
- Sequester carbon:
  Vegetation and soils take in and store carbon. This reduces the amount of CO_2 in the atmosphere and thus works to mitigate global warming.
- Enhance habitats:
  Even small amounts of vegetation can provide habitat for birds, insects, mammals, reptiles, and amphibians. Additionally, green infrastructure can create a link between habitats, allowing wildlife to move between otherwise isolated areas. Decreasing stormwater runoff, thus reducing pollution and erosion, can improve the quality of aquatic habitats (U.S. EPA 2015a).
- Green streetscapes:
  Adding diverse vegetation to an urban environment can transform an otherwise unsightly neighborhood into one that is lush and green.
- Save money:
  By reducing the need for intensive gray infrastructure systems such as pipes and large detention facilities, the costs of managing stormwater can be lowered (U.S. EPA 2015a). Also, when gray systems fail (eg. culvert collapse) it is expensive to fix them.
- Educate communities about watershed health:
  Educational signs near green infrastructure can help educate community members about the impacts of stormwater on watershed health.

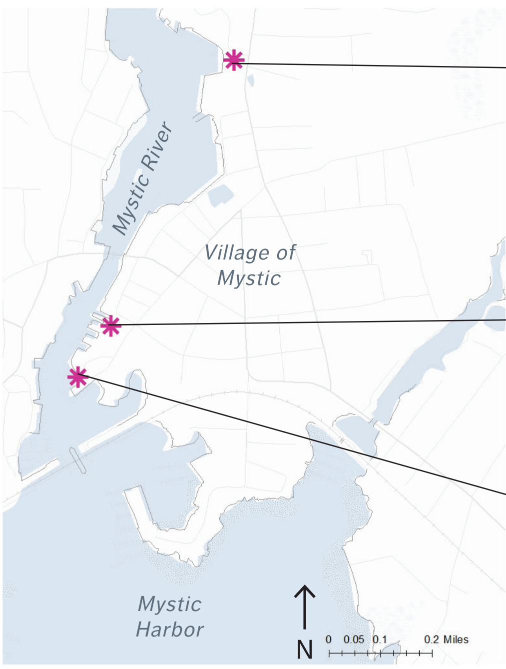
PRELIMINARY LOCATIONS FOR GREEN INFRASTRUCTURE

Preliminary locations for green infrastructure were determined based on community input, information from the Stonington town engineer, Scot Deledda, and the location of “pollution hot-spots” as defined by the EPA. The analysis process (pages 18-45) includes evaluation of existing conditions in these locations and considers additional locations for green infrastructure interventions.

* COMMUNITY MEETING

A community meeting was held on January 23, 2019. The event was promoted as a community conversation and project kickoff. An announcement in the newspaper and an email from the planning department’s listserv drew 63% of the 40 people in attendance. Of the people there, 64% were between 60 and 80 years old, and 53% have been living in Mystic for over 30 years. Attendees arrived informed about climate change-related threats that Mystic faces, with 77% having either read or being aware of the 2017 *Coastal Resilience Plan (CRP)*. Some in attendance helped create the CRP including members of the Climate Change Task Force, professional ecologists, and planners.

The Conway team gathered information from attendees through a series of activities. Individually and then in groups, community members mapped the areas perceived as most vulnerable to flooding and areas that may be appropriate for green infrastructure. Areas most frequently mentioned by the community as both vulnerable to flooding and appropriate for green infrastructure included Mystic Seaport Museum, Mystic River Park, Washington Street, the Amtrak trainline and station, and the wastewater treatment plant with the adjacent marsh. For the community break-out activity, a map of the Stonington side of downtown Mystic showed priority intervention areas in the *Coastal Resilience Plan*. Given the feedback by community members from both the town of Groton and Mason’s Island, the Conway team expanded the project study area to include portions of Groton and Mason’s Island.



Mystic Seaport Museum

Mystic River Park

Mystic Seaport Marina

* COMMUNITY OBSERVATIONS

Community members in attendance were very open to applying green infrastructure in the village of Mystic, both in residential and non-residential settings. They identified potential areas for site-specific interventions.

They expressed an urgency to address flooding issues and implement strategies for climate change resilience. Community members suggested a range of mitigation and adaptation techniques, from ecological conservation to policy changes, as the next steps to implement strategies presented in the *Coastal Resilience Plan*. The most frequently mentioned inland green infrastructure techniques included floodable parks, rain gardens, and permeable pavers and porous asphalt. Coastal green infrastructure intervention priorities included creating living shorelines and protecting or stabilizing existing tidal marsh wetlands.

On the surveys distributed at the meeting, some community members emphasized the importance of strong political leadership; they urged the towns of Stonington and Groton to work together, and advocated changes to zoning and regulations that would allow homeowners to protect shoreline properties and/or install soft shorelines. Additionally, several people in attendance stressed that repairs to failing infrastructure outfall valves would help prevent flooding caused by water backflow through the storm drains at high tide. Many community members also saw the potential for incentives to encourage home-scale green infrastructure, to finance residential adaptation projects like elevating homes and creating floodable first-floors, and to slow development in flood-prone areas.

Many community members stressed the importance of outreach and education as a critical way to raise community awareness about climate change, connect residents to their impacts on local watersheds, and educate homeowners about landscaping, green infrastructure, and not using pesticides. An example of outreach they suggested is implementing projects such as rain gardens in public parks.

Community members from Stonington, Groton and Mason's Island gathered at the January 23rd Community Meeting
(Middle photo by Catherine Hewitt of The Westerly Sun)

* MEETING WITH TOWN ENGINEER

The town engineer, Scot Deledda, led the Conway team on a tour of flood-prone locations in the village of Mystic. He identified three main locations as both areas of localized flooding as well as opportunities for intervention. He welcomed and encouraged the implementation of green infrastructure strategies that would decrease stormwater runoff, intercept pollutants, reduce flooding, and assist the Town of Stonington to comply with the Municipal Separate Stormwater Sewer System (MS4) permitting requirements.

The former Fourth District Voting Hall is a 0.6-acre vacant lot with a small unused building owned by the town. According to Mr. Deledda, the site has been considered for a new parking lot, but the Town has no immediate plans for its development.

Just beyond the Fourth District Voting Hall on Church Street, water floods both the street and the parking lot of St. Patrick's Church. This area was also recognized at the community meeting as an important community asset vulnerable to frequent flooding.

Washington Street, which includes a mixture of residential and commercial uses, is particularly vulnerable to storm surge and tidal flooding; it is especially close to the coastline and a tidal marsh abuts a portion of the southern perimeter.

All three areas are lower in elevation than most of Stonington and are located downtown where runoff collects and drains much slower due to a high concentration of impervious surface. Due to their placement in the landscape and proximity to the coast, stormwater catchment basins also backflow during high tides and storm surges, erupting into the streets and exacerbating flooding.

In addition to the flooding issues at the 4th District Voting Hall, Church Street and Washington Street, the Mr. Deledda also encouraged interventions at Mystic River Park on Cottrell Street, the Mystic Seaport Museum, Seaport Marine, and Apple Rehab nursing home. These same sites were identified by the community as areas vulnerable to flooding.

4th district voting hall

Church Street

Washington Street

PROJECT GOALS

This report examines and further develops the strategies recommended in the *Coastal Resilience Plan*, identifying how they might apply to physical conditions in Mystic, with the intention of testing how such interventions could help preserve the history and culture of a thriving coastal village in the face of climate change. Funded by The Nature Conservancy and guided by the Town of Stonington, this report includes illustrative designs that can help the town of Stonington visualize stormwater management design interventions in residential and non-residential areas within the village of Mystic. The design challenge is to analyze existing conditions and propose interventions that maximize ecological functions and accommodate predicted increases in precipitation within space constraints while complementing the character and tourist economy of the historic village.

This report also explores the potential application of proposed Best Management Practices for compliance with the Municipal Separate Storm Sewer System (MS4) permit requirements outlined in the most recent Stonington Stormwater Management Plan (SMP). The water quality study results described in the Stonington SMP included an outline of potential sources of pollutants, including nitrates, phosphorous and bacteria. The Best Management Practices outlined in the MS4 includes mitigation strategies that help to intercept these pollutants and raise community awareness.

This report also considers adaptation strategies not presented in the SMP or MS4. Extending designs beyond mitigating flooding and runoff pollution, concepts and strategies outlined in this report are designed to address other climate change related issues including ecosystem degradation, depleted groundwater supply, and pollinator collapse. The strategies explored have co-benefits including reducing urban heat island effect, noise pollution, and carbon emissions, while improving air quality and greening the village.

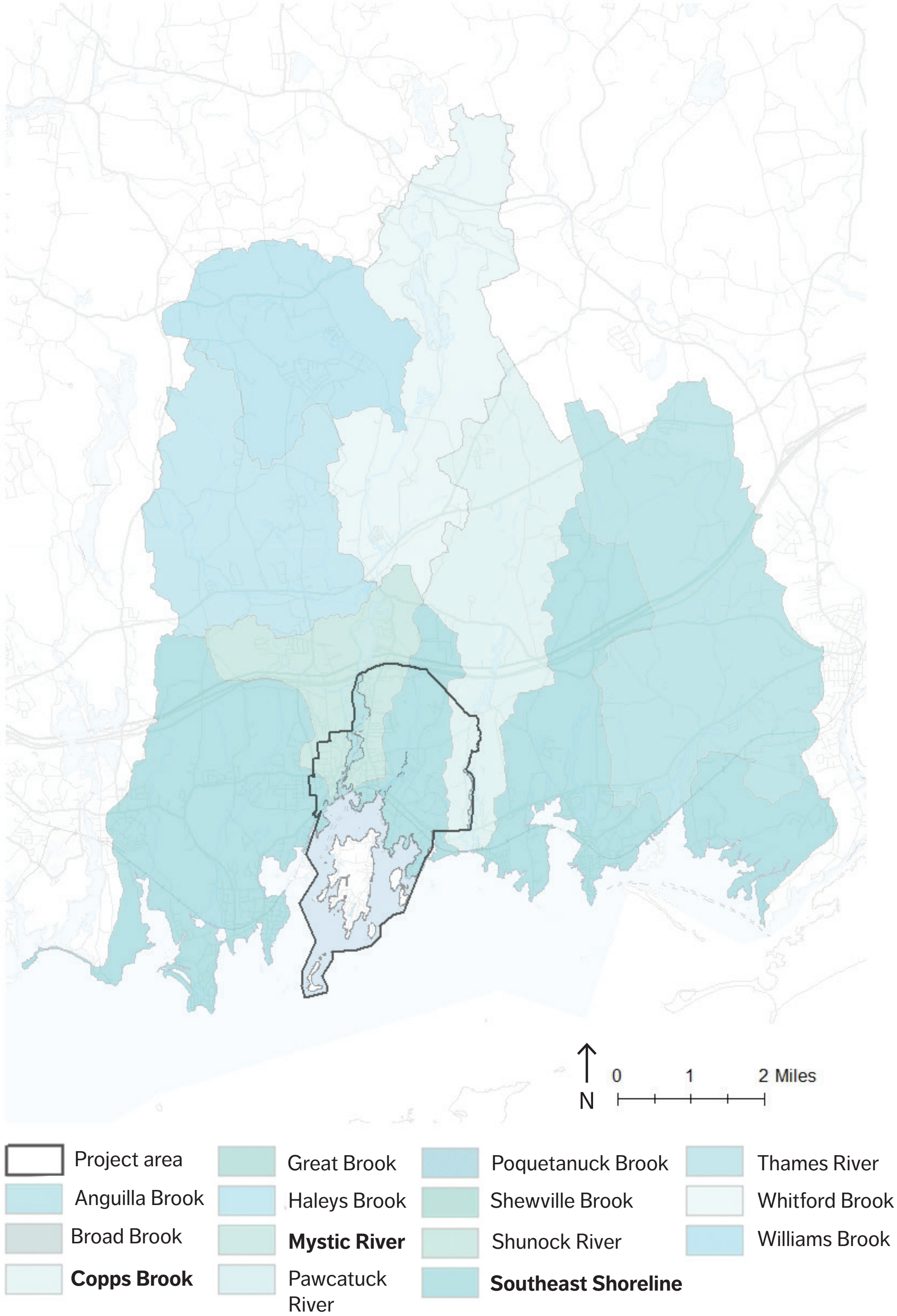
This report also intends to help create a culture of sustainability in Mystic by engaging the public and demonstrating green infrastructure strategies in tourist areas and historic neighborhoods. While these initial concept designs are specific to the village of Mystic, they are intented to help develop strategies and templates that can be replicated in other similar coastal communities. The site analysis that follows examines challenges and opportunities related to stormwater management and flooding in Mystic.

Analysis

Existing conditions of the project area were analyzed using data in ArcMAP, Google Earth Pro, research, and on-the-ground observations. The results of this analysis informed the type and location of interventions presented in the recommendations section. They point to a need for both spatial strategies and government programs and regulations that reduce the negative impacts of stormwater and strengthen the community’s commitment to climate resilience.

Southeast Coast Major Watershed

Watersheds are defined by the drainage patterns of water traveling from high elevations to low elevations. Topography and land cover affect these patterns. Understanding the watershed context and hydrology of Mystic village and its surroundings is critical to determining locations appropriate for stormwater runoff interventions, intercepting pollutants, and improving water quality in streams and other water bodies.



Watershed Health and Impervious Surfaces

The towns of Stonington and Groton are located within the Southeast Coast major watershed of Connecticut on the Long Island Sound. The project area, which includes the village of Mystic, contains portions of three subbasins of this major watershed. The western portion of the study area drains to the Mystic River, the central portion drains to the Southeast Shoreline, and the eastern portion drains to Copps Brook.

As a result of centuries of coastal development, Mystic's shoreline has changed from its natural state as a dynamic system with intertidal wetlands, salt marshes, and aquatic habitats, to one that is hardened with seawalls and developed with roads, businesses, residences, and marinas. Twenty percent of the project area is covered by impervious surfaces, a significant portion of which is concentrated along the Mystic River and Route 1. Within the project area the Mystic River watershed has 38% impervious cover, the Southeast Shoreline watershed has 17% impervious cover, and the Copps Brook watershed has 9.25% impervious cover. Much of the impervious surface cover comprises roads and parking lots, which are used heavily during the peak tourist season (June-October).

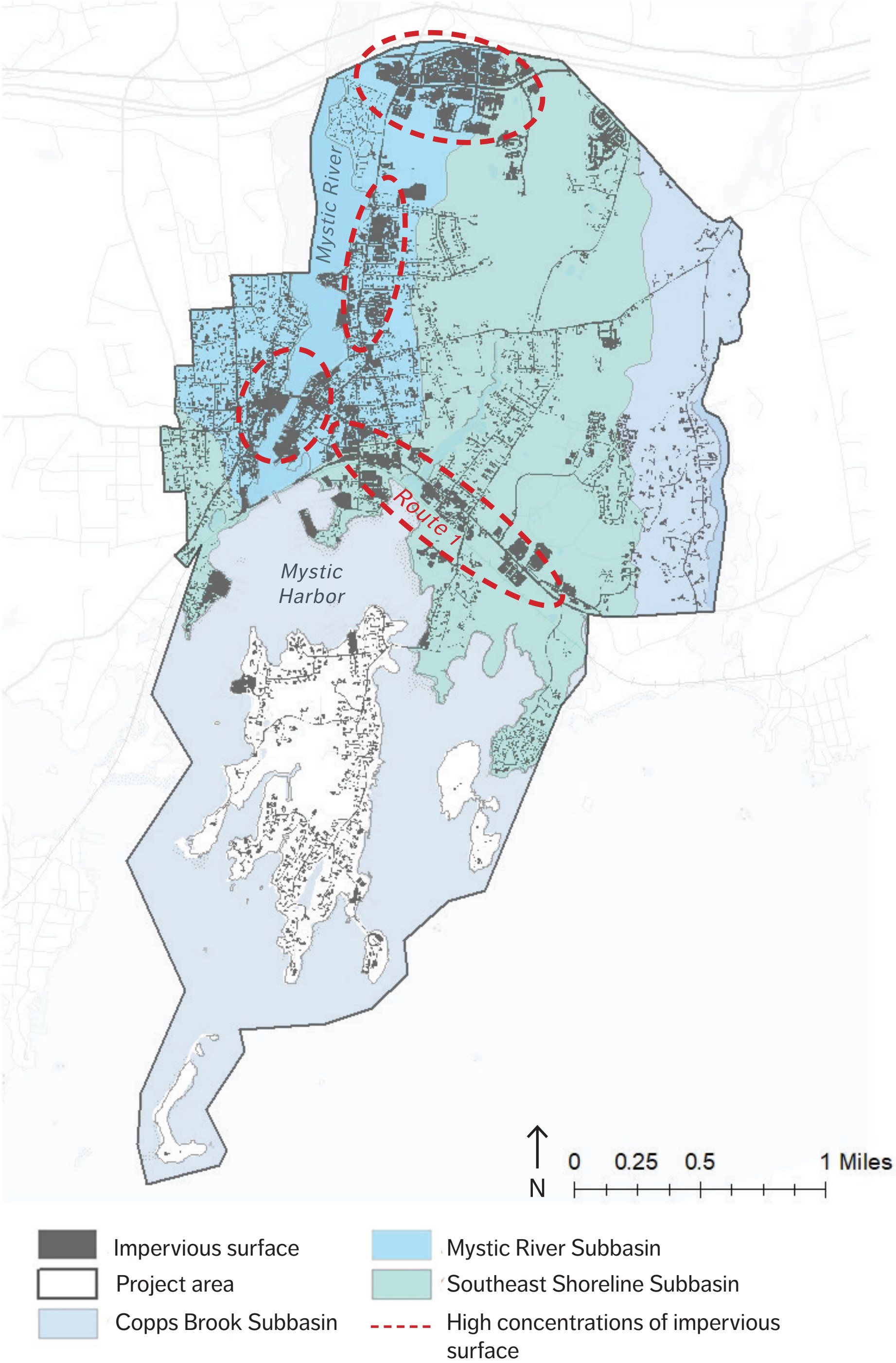
The amount of impervious surface in a given area is also closely tied to watershed health. Researchers found that biological, chemical, and physical water quality indicators in streams declined in health in watersheds with >10% impervious cover, resulting in a decrease in insect and fish diversity and an increase in pollutants and sediment (Center for Watershed Protection). Watershed health is especially important in communities like Mystic that rely on water quality to maintain healthy coastal ecosystems that help buffer the impact of storms and provide economic and cultural benefits.

Areas with a higher percentage of Directly Connected Impervious Areas (DCIA), continuous impervious surfaces that discharge runoff into a storm drain or water body, often have larger volumes of stormwater runoff. When water runs off impervious surfaces, it increases in velocity and temperature, and picks up pollutants such as sediment, nutrients, herbicides and pesticides, bacteria, heavy metals, and other harmful chemicals (U.S. EPA 2018a).

In urbanized areas like Mystic, when rainfall hits impervious surfaces that have absorbed heat from the sun like rooftops, asphalt, and concrete, the runoff absorbs the heat and mixes with particulates, toxins, and fertilizers as it washes over these surfaces. When this runoff enters water bodies, either via overland flow or storm sewer systems, it has negative impacts on water quality, erodes stream banks, and damages wildlife habitats. Negative effects on water quality include depleted oxygen levels due to temperature increases and algae blooms, depleted habitats, and disruption of ecological processes.

Impervious surfaces can also contribute to localized flooding because intense storms and heavy rainfall quickly oversaturate areas, creating sheet flow that channels into runoff as it moves downhill. As stormwater rapidly collects over large impervious areas, these channels become streams that overwhelm stormdrains, creating flooding from accumulated stormwater in low-lying areas.

Concentration of Impervious Surface in Mystic Watersheds



Impaired Waters

Impaired waters are identified by the Connecticut Department of Energy and Environmental Protection every two years (Fuss & O'Neill). Stonington's most recent Stormwater Management Plan (2017) indicates there are impaired waters in all three watershed subbasins: the Mystic River at the mouth and midshore, inner Stonington Harbor, and Copps Brook. This is due to high levels of nitrogen, phosphorus, and bacteria. Potential sources of nitrogen and phosphorous pollutants include vehicular toxins, fertilizers, pesticides, herbicides, yard waste like grass clippings and leaves, detergent use, and construction site sediment. Bacterial pollutants may be present due to pet waste, waterfowl and livestock or horse manure, sanitary cross-connections and leaky septic systems.

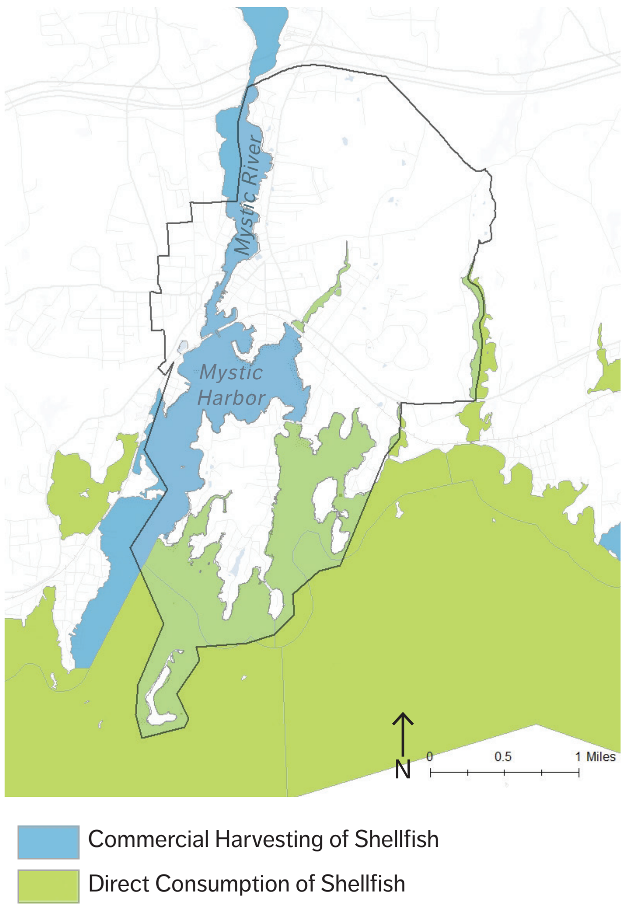
Contributors to impaired waters include point-source and non-point source water pollution, a designation that is defined by the ability to trace the origin of pollutants to a specific source and that dictates the location and type of intervention appropriate for treating it. Runoff from impervious surfaces is an example of non-point source water pollution.

Changing landscaping habits such as reducing or eliminating use of fertilizers, herbicides, and pesticides can reduce levels of phosphorus and nitrogen in runoff. Levels of bacteria in the water seem to have been reduced following updates to Stonington's wastewater treatment plant in 2015, with more recent research shown in the adjacent map indicating that these same areas are considered safe for shellfish harvesting, implying that the water quality and habitats may be recovering (Benson). Ongoing water quality testing is being conducted by the University of Connecticut, the Town of Stonington and citizen-lead organizations like Clean Up Sound and Harbors (CUSH). However, Mystic's storm sewer system still conveys untreated pollutants from roads into water bodies.

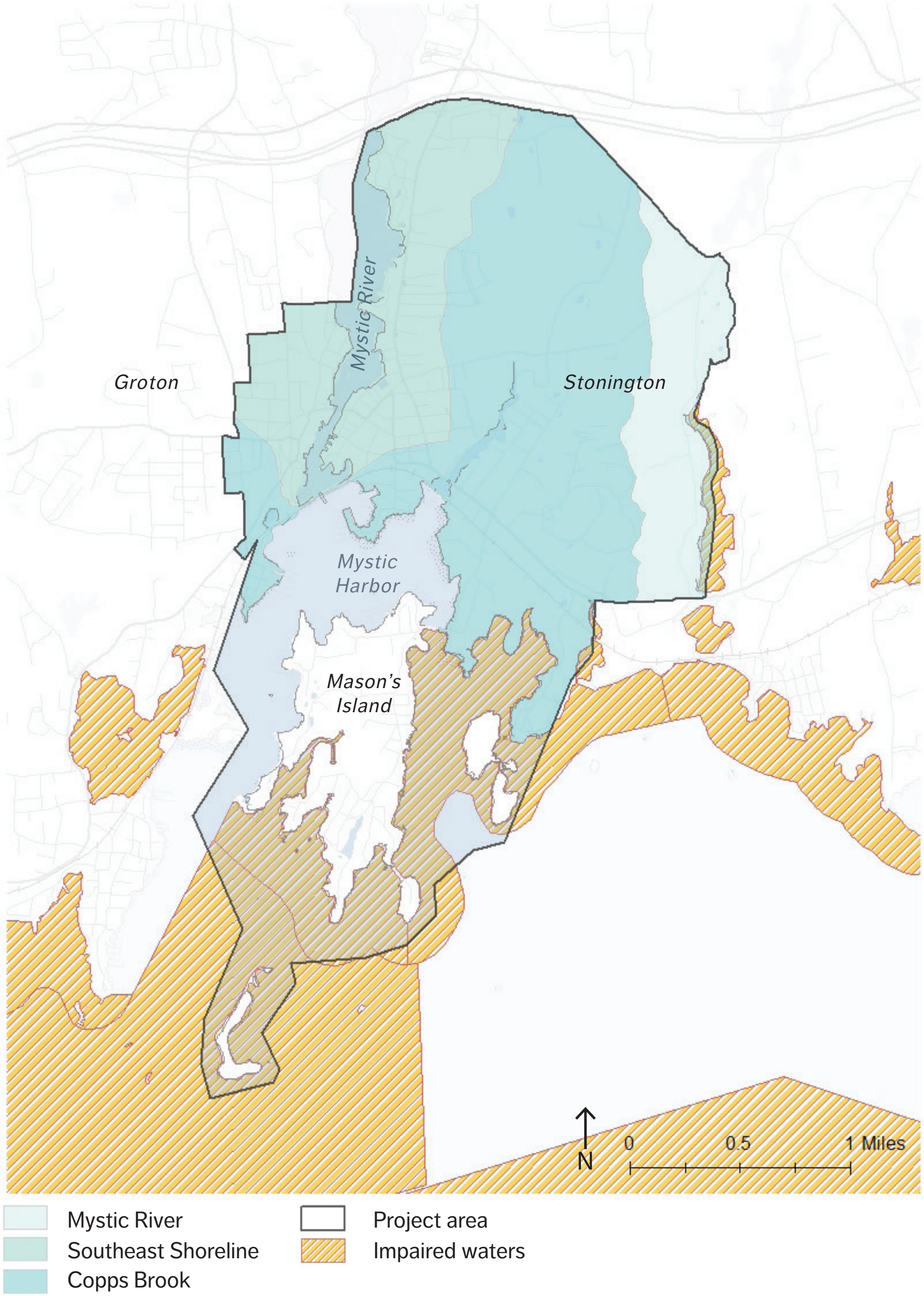
FIRST FLUSH

The first few minutes of a storm generates runoff with the highest concentration of pollutants. This is commonly referred to as the "first flush". Green infrastructure that intercepts the first flush can have positive effects on water quality by slowing runoff, cooling water temperature, filtering toxins, and allowing water to infiltrate, evaporate, or be absorbed by plants. In Mystic, green infrastructure that treats not only the first flush but also larger quantities of runoff may be necessary, especially in light of climate predictions.

Federally Assessed Estuaries for Shellfish Harvesting



Impaired Waters Along Coastal Areas of Mason's Island and Stonington



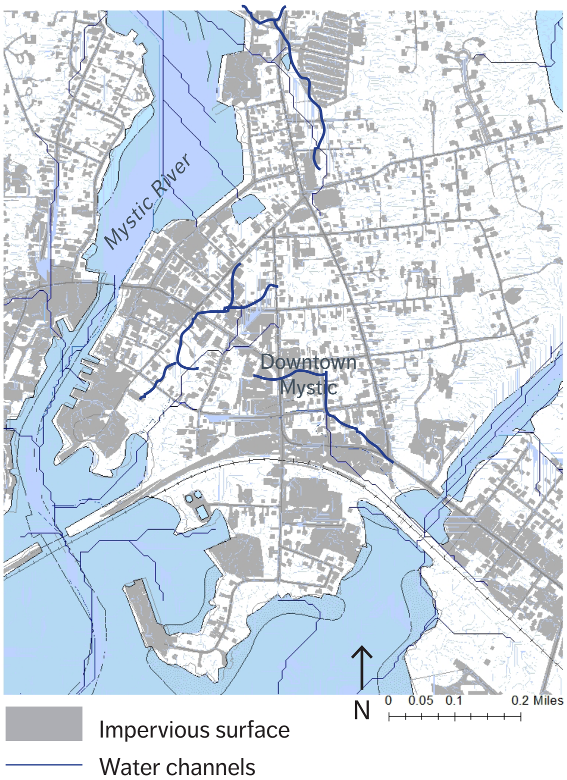
Influence of Slopes and Topography on Drainage

The village of Mystic is primarily flat in the downtown area with an elevation of only 0 to 5 feet above sea level. Downtown Mystic is bordered by a large north-south ridge to the east that slopes toward the downtown at >1% pitch. Large volumes of stormwater move quickly down steep roads without infiltrating into the soil. As it moves, runoff picks up sediment and pollutants and can create extensive erosion. Green infrastructure can be used to intercept and slow runoff, allowing it to percolate or be absorbed thereby helping prevent pooling or flooding in low-lying, downhill areas.

SIMULATED RUNOFF CHANNELS

Using topography and impervious surface data to simulate runoff flow direction and accumulation in GIS reveals the heaviest areas of accumulation in low-lying areas (indicated by dark blue lines). Areas upland from these areas of accumulation are optimum places for interception strategies.

Heavy Flow Accumulation in Downtown Mystic

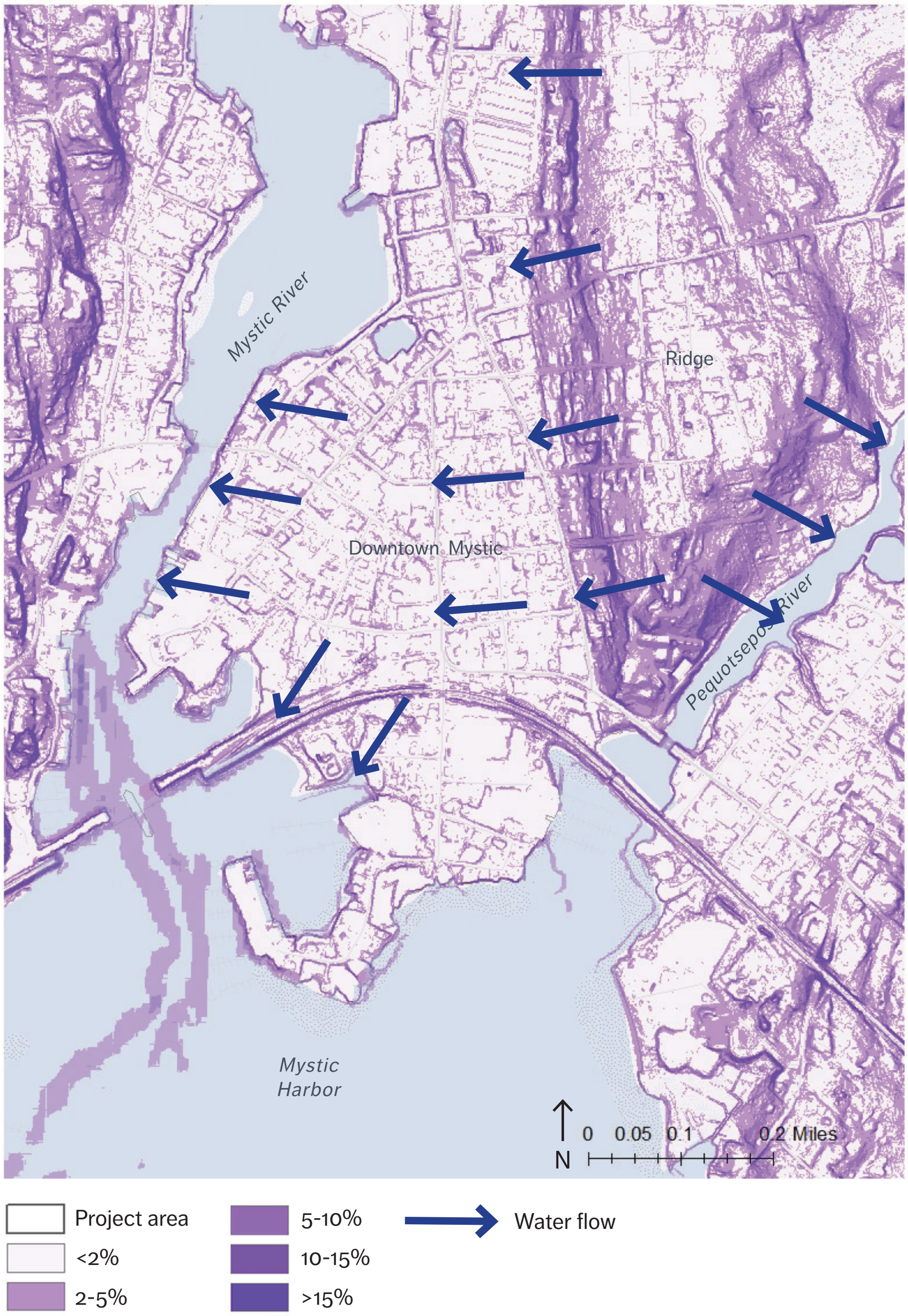


UPLAND AREAS ARE CRITICAL INTERVENTION SITES

Upland areas in Mystic have less impervious surface coverage than low-lying downtown Mystic Village. These areas are largely residential. A variety of home-scale interventions such as permeable asphalt or pavers to reduce runoff, raingardens for bioretention, and rainwater harvesting through cisterns and rain barrels can slow and infiltrate stormwater before it reaches downtown Mystic Village. A combination of interventions on many properties has the potential to intercept large volumes of stormwater runoff. Because a large part of this area is residential, it is necessary to encourage and incentivize homeowners to implement these interventions.

Intercepting stormwater in upland areas is also critical because the heavier development of the downtown commercial and residential areas may limit the size and scope of green infrastructure that can be implemented. A portion of the runoff that accumulates in these low-lying areas may be intercepted higher up in the watershed.

Drainage and Percent Slope in Downtown Mystic



Pollution Hotspots in Downtown Mystic

Priority pollution hotspots were determined using Geological Information Systems (GIS) software analysis of land use based on activities that carry higher pollution loads as identified in the MS4 permit (Fuss & O'Neill). Hotspot areas with the greatest impact on waterways were identified by their proximity to simulated runoff channels and areas of accumulation created in GIS based on topography.

Stonington's MS4 permit states that infiltration of stormwater should be restricted in areas with higher pollution loads, because of the risk of contaminating drinking water supplies. In Mystic, this includes areas with high concentrations of vehicular activity including cars and boats, high traffic commercial areas, and sites with potential industrial toxins. Many of these hotspots in Mystic are along waterways. The MS4 recommends pretreatment of polluted stormwater runoff in these hotspot areas. Applying green infrastructure techniques such as intercepting, slowing, and channeling runoff through a bioswale can help break down pollutants and purify runoff (U.S. EPA 2007).

1

Shell gas station

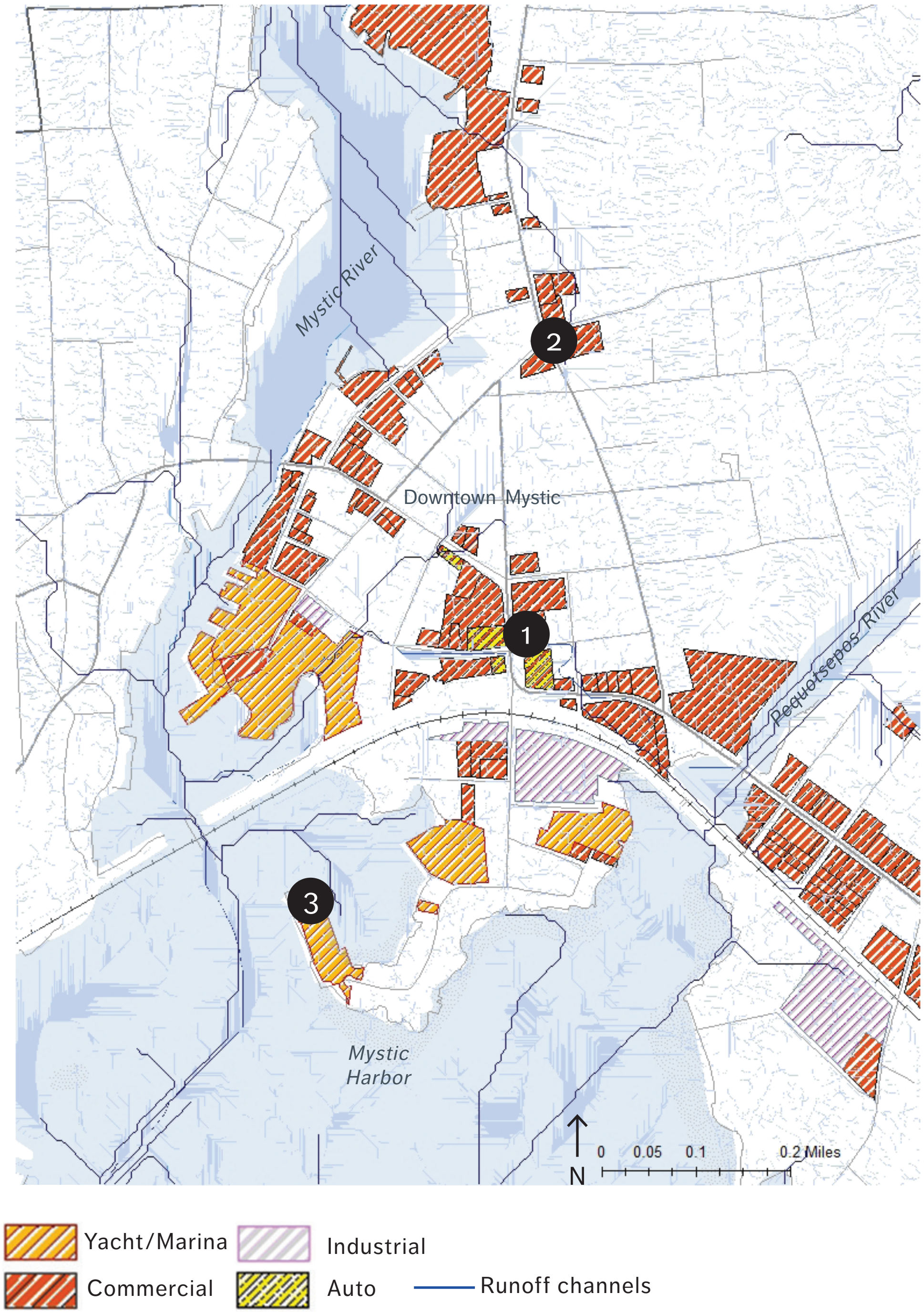
2

Office building

3

Yacht/Marina

Primarily Commercial and Yacht/Marina Pollution Hotspots in Downtown Mystic



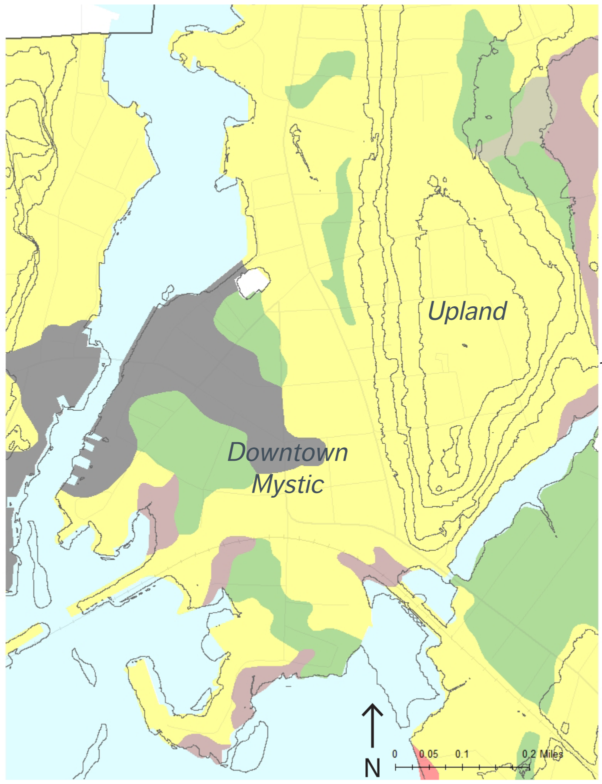
Soil Drainage

Soil types throughout the project study area, particularly in areas uphill from downtown, are primarily well draining. Low-lying areas along waterways and the coast typically contain poorly drained marsh or wetland soils. This implies that any green infrastructure interventions in upland areas may be able to use native soil for infiltration. Depending on percolation tests, infiltration may be possible in low-lying areas. In urban areas soil profiles are typically more compacted. Once impervious surfaces are eliminated or reduced these soils will likely need to be amended and engineered to allow for percolation.

HIGH WATER TABLE

The USDA's Web Soil Survey indicates that in downtown Mystic, there are areas where the depth to water table is approximately 18 to 24". Specific soil qualities and characteristics would need to be confirmed through further soil testing and by evaluating drainage capacity by conducting a percolation test.

This shallow depth to water table may limit infiltration. When infiltration is not possible, options for temporarily storing stormwater runoff and slowly releasing it into the stormwater management system should be considered.

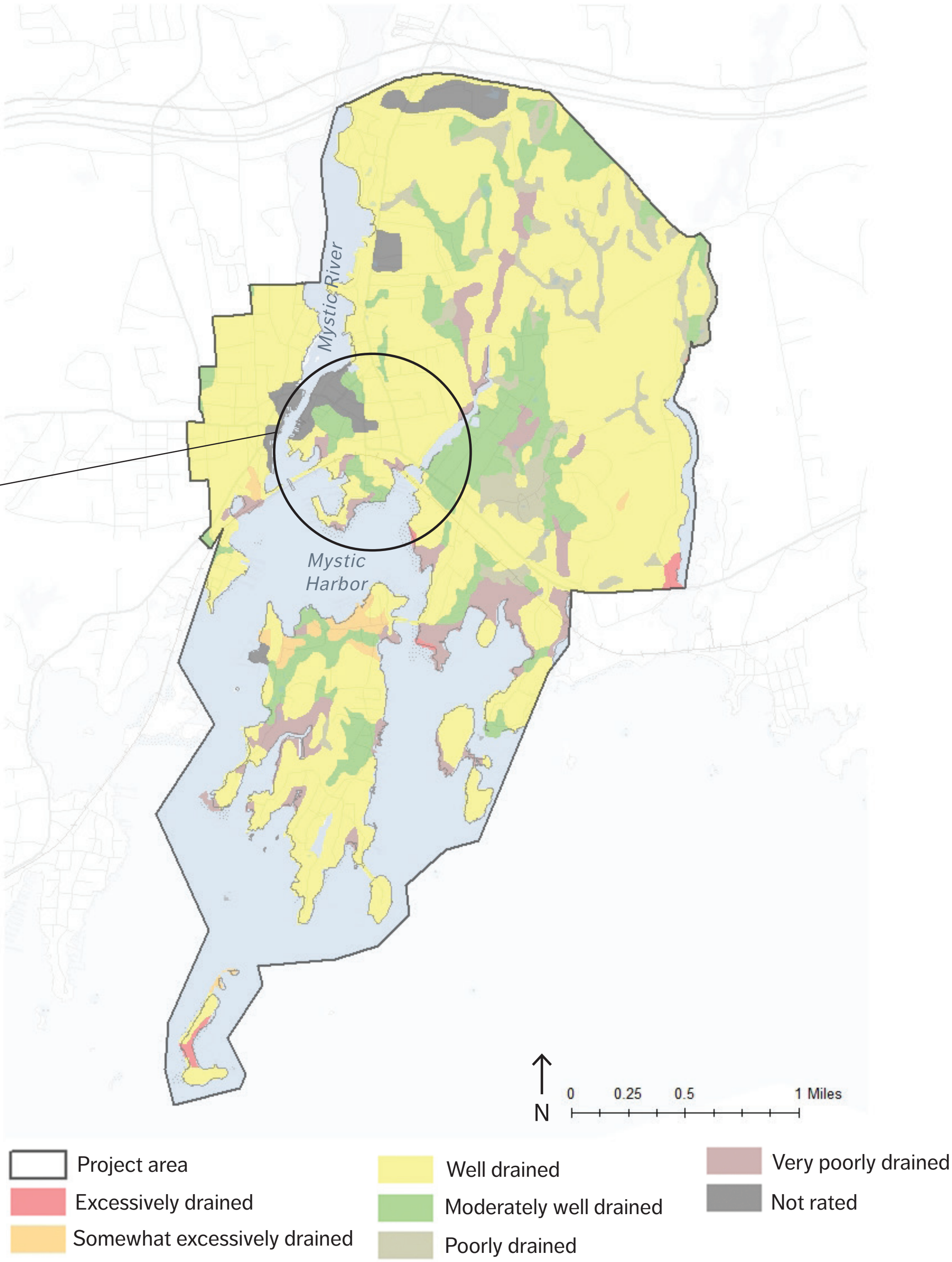


SLOW-SPREAD-SINK VS. SLOW-FILTER-RELEASE

In upland well-draining areas with greater depth to water table, stormwater interventions that slow, spread, and filter runoff may be suitable. Intercepting runoff high in the watershed can help to reduce incidents of flooding in lower lying areas.

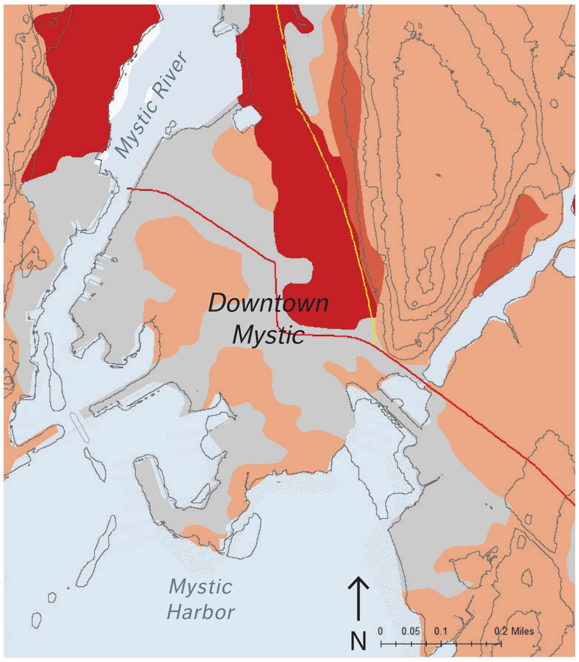
Much of downtown Mystic is in low-lying areas with a high-water table. Because infiltrating runoff may not be possible in these areas, stormwater interventions that slow, filter, and slowly release the "first flush" of surface runoff back into the stormwater management system may be appropriate. When infiltration is not possible, stormwater interventions can still intercept, clean, and temporarily store water until after the peak storm event.

Predominantly Well-Draining Soils in Project Area



Soil Types Suitable for Green Infrastructure

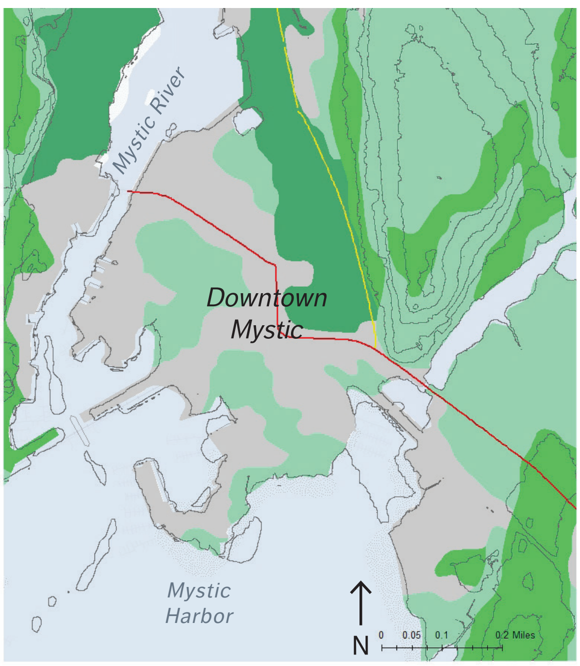
Using the most detailed soil geographic data available, the Connecticut office of the Natural Resources Conservation Service (NRCS) created soil interpretations for suitability of various green infrastructure techniques for stormwater runoff management based on soil type and characteristics. The following analyses can be used to help determine areas that may be appropriate for permeable pavers, infiltration systems, retention basins, and detention basins. Further site-specific analyses will need to be conducted in order to confirm applicability of these suggestions on a case-by-case basis.



SOIL SUITABILITY FOR STORMWATER INFILTRATION SYSTEMS

This analysis of soil data indicates that stormwater infiltration systems like bioretention areas and bioswales are most suitable in some well-draining, low-lying areas such as along Route 27, at the base of the steep ridge that slopes toward the downtown. This data also indicates that downtown and upland areas are considered least suitable for infiltration systems. Because USDA soil data analysis indicated upland areas are primarily well draining soils, and low-lying areas have a high water table, more site specific soil analysis is recommended.

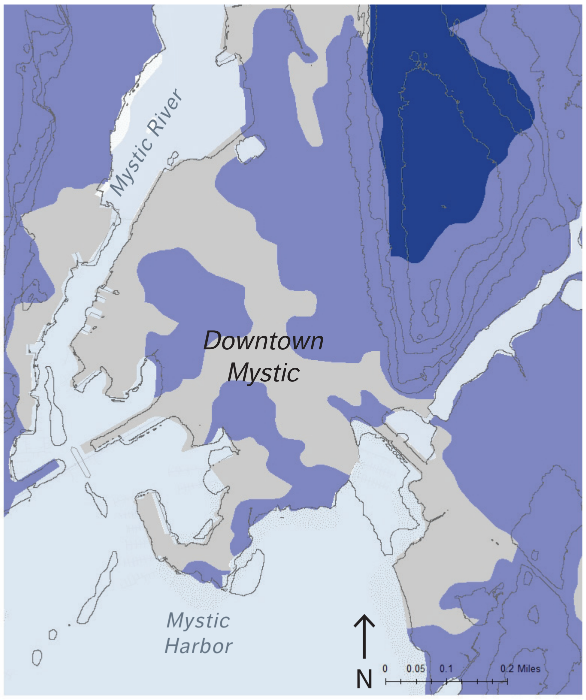
State Route 27
U.S. Route 1
Most Suitable
Somewhat Suitable
Least Suitable
Not Rated



SOIL SUITABILITY FOR PERVIOUS PAVING

This analysis indicates that pervious paving is also most suitable in many of these same well-draining, low-lying areas west of Rt 27 and north of Rt 1. This supports suggestions for using permeable paving such as permeable asphalt or permeable pavers for parking areas, streets, and sidewalks in the downtown. Percolation testing is recommended to determine infiltration rates and depth to water table should be confirmed when considering underground stormwater storage options below any permeable parking areas.

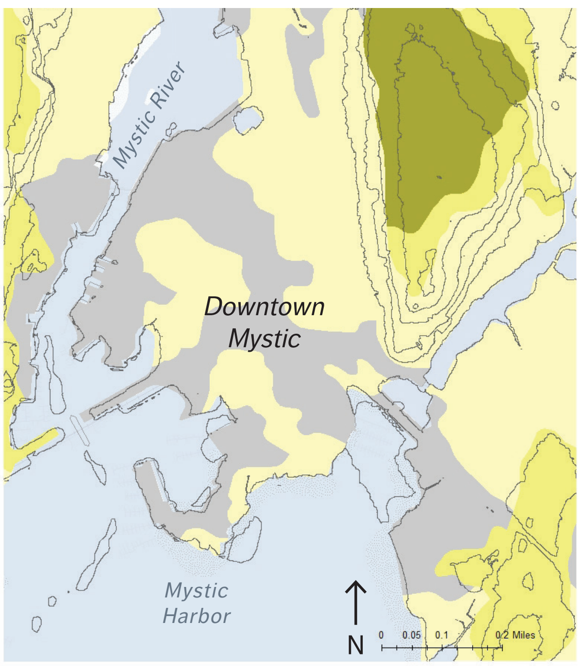
State Route 27
U.S. Route 1
Most Suitable
Somewhat Suitable
Least Suitable
Not Rated



SOIL SUITABILITY FOR WET EXTENDED RETENTION BASINS

This analysis indicates that upland areas are most suitable for wet extended detention basins such as stormwater retention ponds and permanent pools. While this may suggest that soils here are not well draining and/or have a shallow depth to water table, the NRCS Websoil Survey indicates these same areas as being composed of well-draining soils.

Most Suitable
Least Suitable
Somewhat Suitable
Not Rated



SOIL SUITABILITY FOR DRY DETENTION BASINS

Interestingly, these same upland areas are rated as most suitable for dry detention basins. These basins are designed temporarily hold volumes of stormwater runoff and drain over 48 hours. Site-specific analyses of percolation rates and depth to water table will help determine applicability of dry detention basins or wet extended retention basins. Depending on site specific analysis, upland areas may be appropriate for either wet or dry detention basins. Any basins can be made non-permeable for extended detention if lined in bentonite clay upon construction.

Most Suitable
Least Suitable
Somewhat Suitable
Not Rated

SALT INUNDATION OF SOILS

As previously mentioned, most of downtown Mystic has an elevation of 0' to <5', which means there is a chance of salt inundation from backflowing storm drains and coastal flooding. Coastal salt spray, tidal areas, storm surges and hurricanes bring seawater, brackish or tidal surge water mainland. When salt inundation occurs it can have damaging effects on soil quality, plants and fresh water supplies. As flood waters recede or infiltrate into the soil, salts are left behind that have damaging effects on soil structure, making soil more dense and compacted. The sodium and chloride left in the soil from saltwater are toxic for many plants. This can be visible through leaves drooping, browning, or dropping from the plant. Salt can damage plants by drawing water out of plant roots which can starve roots, stunt plant growth and make plants more susceptible to drought. When absorbed by plants that aren't tolerant of saltwater, salt can kill leaves and stems, causing further stress or ultimately kill the entire plant. Finally, saltwater can mix with freshwater supplies like groundwater or irrigation ponds and contaminate shallow wells or irrigation supply reserves for agriculture.

Salt levels in soil can eventually be depleted through rainfall depending on the soil type and depth to the water table. Areas with high water table and clay soils can take up to several years to return to normal, but areas with sandy soils can be restored in as little as a year of normal rainfall. The rain washes the salt deeper into the soil profile where it has less impact on plant health. Salt also has less effect when plants are dormant, as they are not absorbing water during winter months, and rain and snowmelt can help move salts deeper into the soil before the plant returns from dormancy.

After Superstorm Sandy, Cornell University and Rutgers University recommended several steps to restore soil after salt water flooding in lawns and gardens in order to reduce these harmful effects on plants. Fortunately typical lawn grasses are fairly salt tolerant. Planting salt-tolerant plants such as coastal panic grass and tall fescue in flood-prone coastal areas is highly recommended.

Immediately after flood waters recede, irrigating soil with 1" flushes of fresh water every few days can help plants survive salt inundation. This speeds up the effects of rainfall by moving salts beyond the root zone. This should only be done where soils are well draining. It is important to refrain from pruning until the plants have completely leafed out and dead branches have been identified, because pruning can cause further stress plants.

Aerating the soil and amending with calcium can help reduce salt content in the soil and help restore the soil profile. Gypsum (calcium sulfate $CaSO_4$) replaces salt in the soil profile and can be mixed into leaf compost or yard-waste compost, helping to feed plants safely without using synthetic fertilizers (as those contain salts). After 3 months, slow-release organic fertilizers may be used to help replenish beneficial bacteria and fungi in soil where salt and osmosis may have depleted the living soil structure.

Soil testing for salt levels is available through University extension offices. Soluble salt levels can be tested on larger sites using an electroconductivity meter with a soil probe. Sodium levels in soils can also be determined through private laboratory testing.

Information from this section is from *Coping with Saltwater Flooding* by Charlene Costaris and *Salt Water Inundation Fact Sheet* by M. Harold.


Panicum amarum, Coastal panic grass

A History of Stormwater Management in Mystic

In 1972 the Federal Clean Water Act (CWA) established a framework for regulating pollutant discharges into waterways and to monitor surface water quality.

In response to the CWA, the EPA created the National Pollutant Discharge Elimination System (NPDES), a permitting system aimed at regulating point-source discharges, or single, identifiable sources of pollution, such as those from factories and sewage treatments plants (U.S. EPA 2018b). While water quality improved as a result, nonpoint source discharges—those from many diffuse sources within a watershed such as stormwater runoff from a large parking lot— were soon recognized as a major source of water pollution nationwide. In 1999, the EPA, recognizing that many nonpoint discharges come from urban areas, created NPDES Phase II to regulate nonpoint pollution from municipal separate storm sewer systems (MS4s) (U.S. EPA 2018b). An MS4 is a storm sewer system operated by a municipality in an urbanized area. These systems collect runoff in pipes and discharge it, untreated, into water bodies.

Stonington was identified by the EPA and the Census Bureau as an urbanized area with an MS4. As such, the Town is required to develop and implement a Stormwater Management Plan (SMP) that outlines strategies and Best Management Practices to reduce the negative impacts of runoff. As part of the permitting renewal process, a new SMP was created in 2017 and will be implemented over the next five years. The plan aims to address stormwater through six program elements, referred to by the EPA as "minimum control measures," and focus efforts on locations with impaired water bodies and Directly Connected Impervious Areas (DCIA) that exceeds 11% (Fuss & O'Neill). DCIA are continuous impervious surfaces that discharge runoff into a storm drain or water body. These measures include:

- Public Outreach and Education
- Public Participation
- Illicit Discharge Detection and Elimination (IDDE)
- Construction Site Stormwater Runoff Control
- Post-construction Stormwater Management
- Pollution Prevention and Good Housekeeping

The town of Stonington currently relies almost exclusively on gray infrastructure to manage stormwater. The most recent Stormwater Management plan addresses green infrastructure, but does not present any plans to implement it as a Best Management Practice. Furthermore, if all measures are implemented, runoff will still be discharged directly into water bodies. However, green infrastructure can help reduce the stormwater impacts within each of the six minimum control measures and can shift the way stormwater is managed, providing numerous benefits.

A municipal outfall discharges untreated stormwater

Existing Municipal Stormwater Management System

Stonington has a separate storm sewer system that collects only stormwater runoff (not wastewater) from impervious surfaces via catchbasins and discharges it untreated into surrounding water bodies.

Community members and municipal government officials have expressed two major concerns in regards to stormwater in Mystic, flooding and water quality. In heavy precipitation events, large volumes of water move from higher elevations and collect in low-lying areas. Additionally, during storm surges or especially high tides, water from the Mystic River and Mystic Harbor enters the outfalls which are concentrated along the coast and backflows through the storm pipes and out the catchment basins into the streets. These conditions can result in both large and small floods that pose a significant risk to Mystic's historic and cultural assets, tourist activity, and day-to-day quality of life. High volumes of runoff can also damage the stormwater infrastructure itself. Stormwater carries pollutants directly into Mystic River, Mystic Harbor, and the Pequotsepos River (Fuss & O'Neill). This can contribute to the impairment of these water bodies.

Although the Town of Stonington is working to reduce the risks of flooding and pollution by implementing Best Management Practices (BMPs) such as regulating runoff from construction sites, limiting the use of deicing materials like salt and sand, and administering a town-wide leaf collection program, it is simultaneously continuing to permit development along the shoreline. As of July 2018, there was more than $100 million in new development proposed in Mystic (Wojtas). The MS4 limits impervious surface for new construction and in some cases mandates on-site stormwater management techniques. However, the addition of Directly Connected Impervious Surfaces (DCIA) often increase the amount of stormwater runoff. Furthermore, the EPA notes that nationally, increased impervious surface in coastal areas and the corresponding decline in coastal wetlands can exacerbate the impacts of coastal storms by reducing the shoreline's ability to buffer wave energy (U.S. EPA 2018a).

By limiting development along the shoreline, implementing measures that significantly reduce impervious surface cover, and treating stormwater at the source, Mystic can reduce the risk of flooding and improve water quality.

Outfall discharging stormwater runoff

Water body where stormwater is discharged

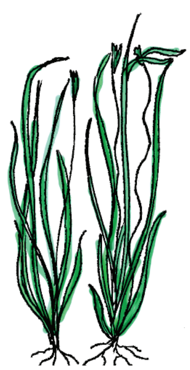
Municipal Seperate Storm System in Mystic

Stormwater and Habitat

The majority of wildlife habitats within the project area are aquatic and hug the coastline where rivers and streams discharge into the ocean. These areas are also near many stormwater outfalls that discharge untreated stormwater from the municipal system. Pollutants from stormwater can negatively impact ecosystem health. For example, excess nutrients and sediment can lead to eutrophication in water bodies, a process that causes plants and algae to become so dense that oxygen levels and light availability become depleted, effectively choking out other aquatic life and leading to habitat loss (U.S. EPA 2018a).

Healthy coastal ecosystems mitigate the effects of climate change by pulling carbon dioxide out of the atmosphere. They also provide ecosystem services such as attenuating wave action during storms and buffering winds. Places like Mystic also depend on a healthy shoreline to maintain the shellfishing and tourism industries. The three Connecticut Critical Habitats within the project area play a significant role in reducing the impacts of storms. These are wildlife habitats identified by the Connecticut Comprehensive Wildlife Conservation Strategy that are considered to be rare and specialized with high species diversity, and highlight ecologically significant areas that should be targeted for land conservation and protection (CT ECO a). Estuarine Beachshore Habitat comprises sandy beaches and dunes which can act as a natural barrier to winds and waves; Estuarine Intertidal Marshes are areas that frequently flood and can absorb wave energy during storm events; and Coastal Woodland/Shrublands have plants such as seaside goldenrod that stabilize shorelines (NOAA). Eelgrass and hard clams also help to mitigate the effects of climate change and improve water quality. Eelgrass beds can reduce the force of wave energy and coastal erosion. They also provide important habitat for other marine life. Hard clams and other types of shellfish can help maintain healthy water quality by removing phytoplankton from the water column and keeping algae populations under control which, if left unchecked, can choke out other aquatic life (Coos Watershed Association). They can also individually filter up to 50 gallons of water a day. However, in polluted environments, shellfish absorb toxins, becoming toxic themselves. This can pose a health risk for human consumption. It can lead to a ban on shellfish harvesting, resulting in detrimental economic impacts.

Green infrastructure can help to improve the quality of stormwater runoff by cooling and removing pollutants from it, thus reducing stress on these downstream ecosystem-service-providing species. Additionally, it can improve wildlife habitat on land by increasing tree canopy cover, decreasing impervious surfaces to allow for salt marsh advancement along the coast, and creating corridors of green space between urban and natural environments. This can be particularly beneficial for species in Natural Diversity Areas that have been identified as Endangered, Threatened or Special Concern under the Connecticut Endangered Species Act (CT ECO b).

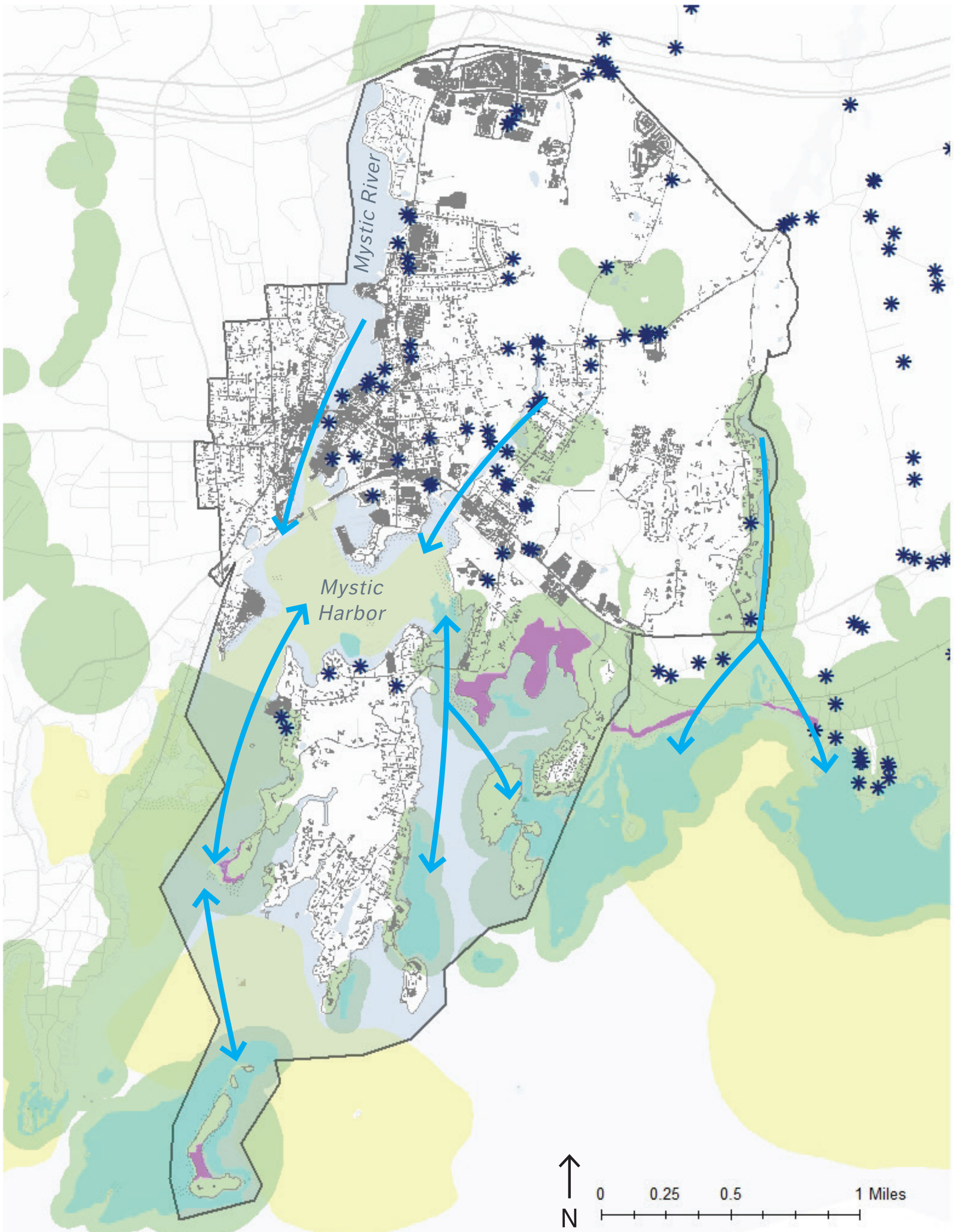


eelgrass

seaside goldenrod

hard clam

Stormwater Outfalls and Water Flow Near Coastal Habitats



Municipal stormwater outfalls
Impervious surface
Project area
Critical Habitat
Eelgrass beds
Natural Diversity Area
Shellfish
Water flow

Photo Credit: Andrew Jameson

Trees and Stormwater

As defined by Naturally Resilient Communities, a project devoted to using nature to address flooding, "urban forestry is the planned installation and management of trees within an urban setting, often within the public right-of-way, parks, and other public lands." "[Urban forests] include both public trees (in parks and forest preserves) and private trees (in backyards and corporate campuses)" (Naturally Resilient Communities). Increasing the urban forest can help to reduce and filter stormwater runoff.

Trees intercept rainwater, slowing the time it takes to reach the ground and allowing some of the water to evaporate from the leaves and bark. Depending on their age, size, and species, a single tree can store 100 gallons of water in their canopy and bark (Frazio). Trees also take in water through their roots and in doing so, absorb trace amounts of chemicals and pollutants which can then be transformed into less harmful substances, used as nutrients, and/or stored within the tree itself (U.S. EPA 2013a).

In addition to reducing runoff volumes and removing pollutants, trees provide numerous other benefits for people including improving air quality, increasing property values, and greening streetscapes (U.S. EPA 2013b). They also help people conserve energy by providing shade, thereby decreasing the heat island effect, and lowering the need for cooling during summer months. Finally, they help mitigate the impacts of climate change through carbon sequestration, the process of removing carbon dioxide from the atmosphere and storing it within the tree itself.

Measuring the Benefits of Trees

Case Study: Indiana
(Stormwater to Street Trees, 2013)

In 2010, the Indiana Department of Natural Resources conducted a statewide street tree benefit study using i-Tree, a software program based on USDA Forest Service Research that quantifies the ecosystem services trees provide. In addition to the numerous environmental benefits, they found that street trees in Indiana provided approximately $24.1 million in stormwater management benefits by intercepting rainfall, reducing changes in streamflow, and improving water quality.

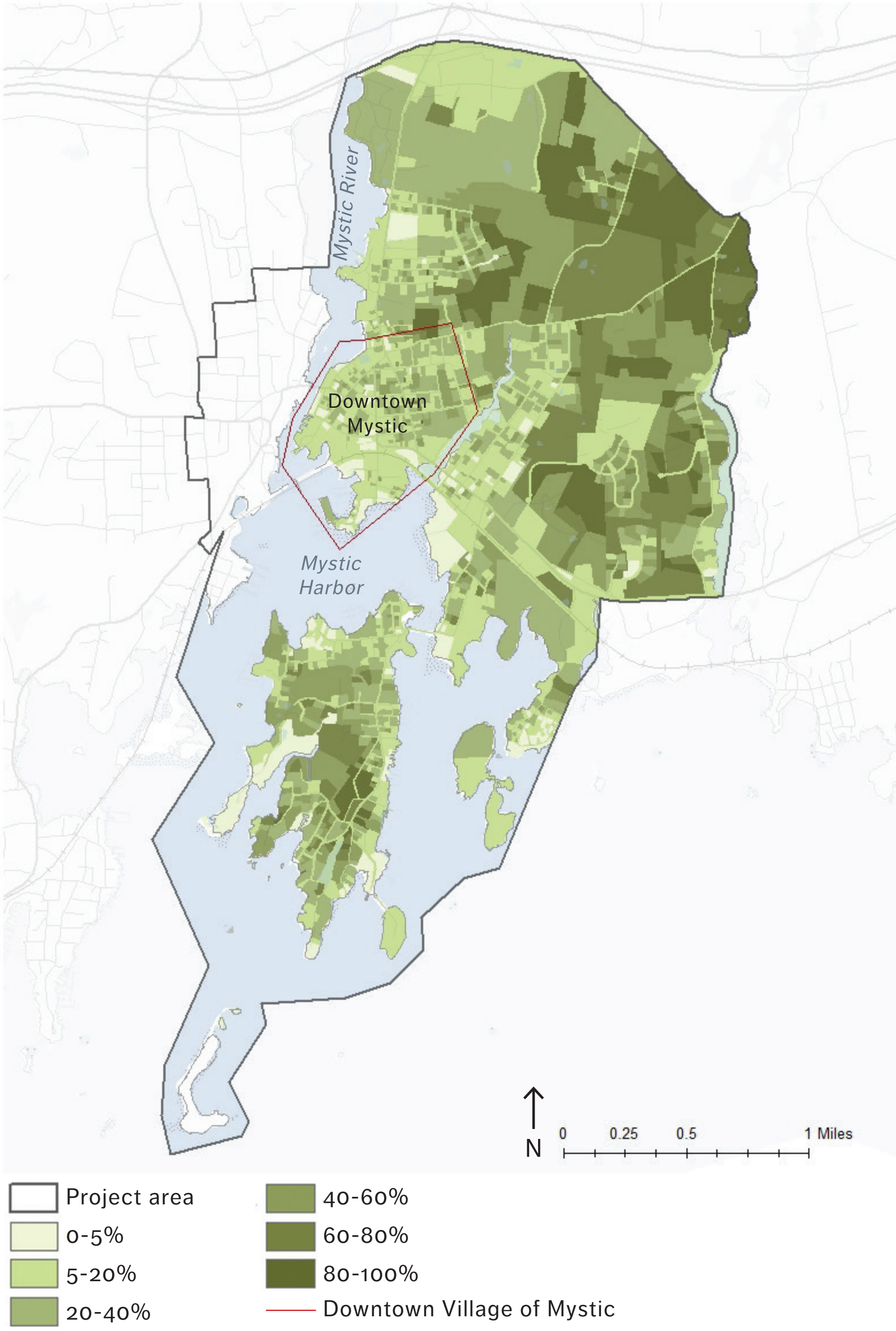
TREE CANOPY

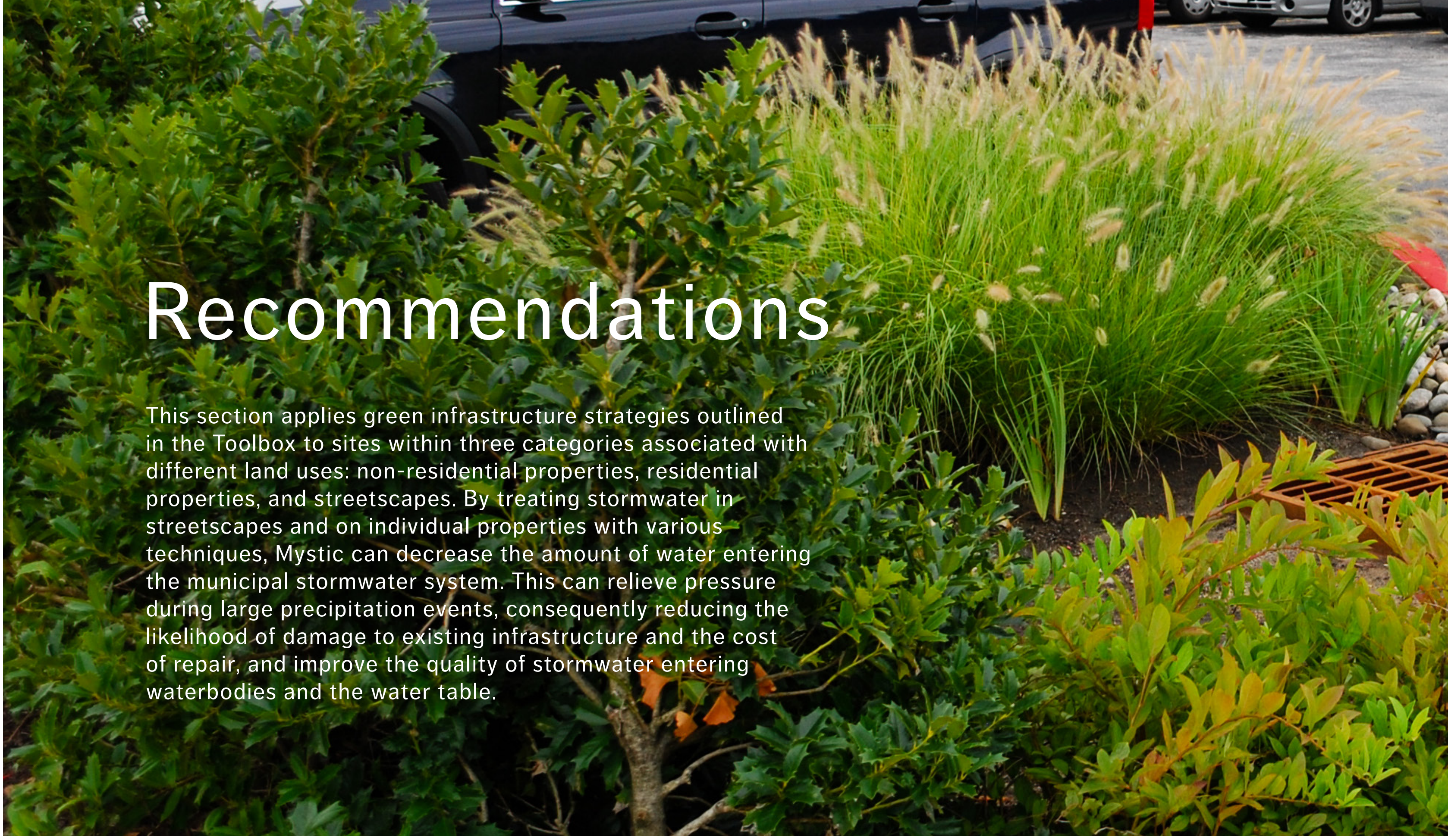
An analysis of Light Detection and Ranging remote sensing data (LiDAR) from the National Oceanic and Atmospheric Administration (NOAA) shows an approximate tree canopy cover of 40% within the project area. Some areas with lower percent tree canopy cover, such as Mason's Island, are covered by other important ecosystems such as salt marsh. However, within the village of Mystic, a significantly more urbanized area, tree canopy cover is reduced to only 33% because of the high density of impervious surface.

Although the project area has a high concentration of buildings, roads, and parking lots, there is still a significant opportunity to increase tree canopy cover. Assuming that planting trees is easier and more successful in undeveloped soils and in areas without existing trees, impervious surface and tree canopy cover were calculated for the project area, the combination of which was subtracted from the total project area, leaving a total of 775 acres where trees could potentially be planted. Assuming an average tree canopy of approximately 40ft in diameter, there is enough space to plant roughly 20,000 new trees within the project area. This analysis does not take into consideration other conditions necessary for tree growth, thus further analysis of soil, sunlight, and water availability should be conducted on a site-by-site basis. Furthermore, reducing existing impervious cover could yield additional space to plant trees. For example, tree boxes can be incorporated into existing impervious surfaces such as parking lots and plazas.

"Volunteers in service of the canopy" planting trees with Tree Northampton, a private citizens group promoting ecological stewardship of Northampton, MA through education, advocacy, and volunteer participation. Volunteers support Northampton's tree program by planting and caring for trees all around the city. Photo credit: Brittany Hathaway.

Percent Tree Canopy Cover in Downtown Mystic





Recommendations

This section applies green infrastructure strategies outlined in the Toolbox to sites within three categories associated with different land uses: non-residential properties, residential properties, and streetscapes. By treating stormwater in streetscapes and on individual properties with various techniques, Mystic can decrease the amount of water entering the municipal stormwater system. This can relieve pressure during large precipitation events, consequently reducing the likelihood of damage to existing infrastructure and the cost of repair, and improve the quality of stormwater entering waterbodies and the water table.

TOOLBOX
OF GREEN
INFRASTRUCTURE
STRATEGIES

Photo Credit: Chesapeake Bay Program

NON-RESIDENTIAL

commercial, industrial, and town-owned properties

Other benefits:

- Demonstrates green infrastructure in highly visible locations (e.g. to shoppers, employees, park visitors, etc.)
- Provides educational opportunities.
- Serves as models for other green infrastructure projects.

RESIDENTIAL

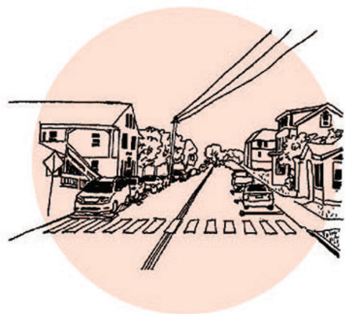
Single-family residential properties

Other benefits:

- Builds partnerships between municipal government and community members.
- Gives residents ownership over watershed health.
- Inspires neighbors to manage stormwater on-site.

GREEN STREETS

Municipal and state-owned rights-of-way including parking lanes, sidewalks, and medians



Other benefits:

- Greens neighborhoods.
- Improves travel experience for vehicles, pedestrians, and cyclists.

Toolbox

The 2017 Stonington *Coastal Resilience Plan* suggests green infrastructure solutions such as permeable paving, green roofs, bioswales, rain gardens, and rainwater harvesting to reduce harmful effects of stormwater runoff on water quality and reduce flooding. Spatial criteria and construction parameters for these and other green infrastructure strategies were evaluated with emphasis placed on those that provide co-benefits including improving air quality, sequestering carbon, increasing wildlife habitat, and greening the village of Mystic. The design parameters that follow are intended to serve as an introduction to a range of tools that may be appropriate interventions in Mystic with applications in other similar coastal communities. Further site-specific analysis is needed before the preparation of construction documents. Based on analyses for the village of Mystic the following green infrastructure strategies were identified as potential interventions:

VEGETATED FILTRATION STRIPS

bioswale, tree trench, flow-through planter

slows, cools, and removes pollutants from runoff.

BIORETENTION FACILITIES

treebox filter, raingarden, bioretention area, green roofs

temporarily stores and removes pollutants from runoff.

PERMEABLE PAVING

permeable asphalt, permeable pavers, structural soil

temporarily stores runoff and infiltrates where soil conditions allow.

RAINWATER HARVESTING

cistern, rainbarrel, dry well, stormwater chamber

stores runoff for reuse or gradual release into the ground or stormwater system.

Sources for construction details on the following pages include:

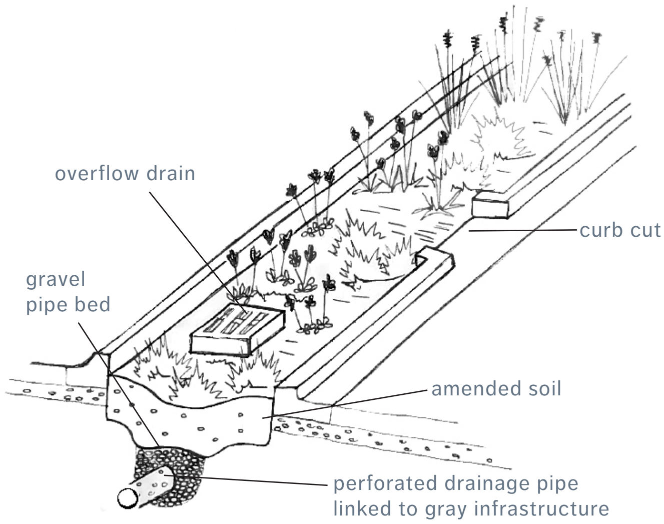
Contech Engineered Solutions, Greywater Action, The Groundwater Foundation, Interlocking Concrete Pavement Institute, LID Urban Design Tools, Maryland Department of Environmental Resources, Minnesota Stormwater Manual, National Association of City Transportation Officials, Philadelphia Water Department, Pioneer Valley Planning Commission, Seepage Control, Inc., Stormchambers, Stormwater Equipment Manufacturers Association, StormTech Subsurface Stormwater Management Chambers, Water Environment Research Foundation, and Whole Building Design Guide.

BIOSWALE *Linear depressed vegetated swale that slows, cools, and filters stormwater runoff using native plants and soils.*

Benefits: Bioswales slow and remove pollutants from runoff while recharging the groundwater if soils permit infiltration. Bioswales typically incorporate hardy native plants that are tolerant of inundation and drought, sequester carbon in their roots, have lower maintenance requirements than non-native plants, and provide habitat for birds and pollinators.

Application: They are commonly used in parks and parking lots, along streets and near residential lawns. They can be integrated with curb extensions in streets, into medians, cul-de-sacs, and other public space or traffic calming strategies.

Limitations: Bioswales are not recommended in locations with low soil infiltration rates because standing water, localized flooding, and other issues can cause problems within the street and sidewalk in an urban environment.



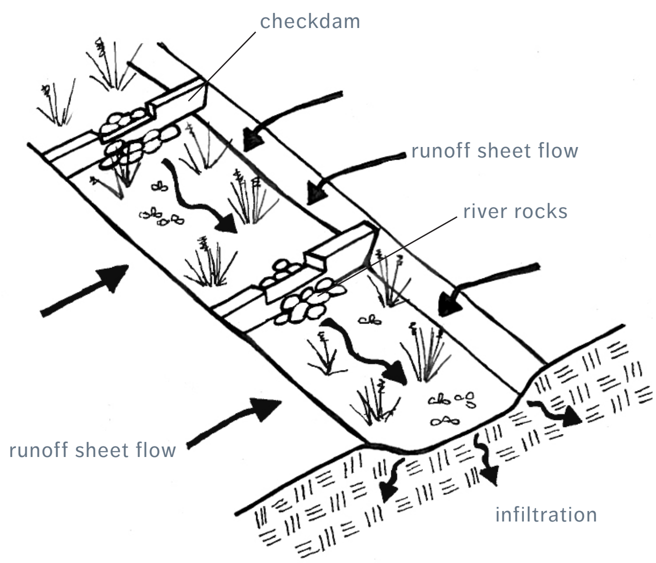
Construction Details: Bioswales must percolate 5–10 inches of rain water per hour and maintain a 5-foot clearance from the bottom of the bioswale to the top of high groundwater table. An overflow or bypass drain system is raised above the soil surface and connected to a gray infrastructure system. Side slopes should be 4:1, with a maximum of 3:1. For areas where curb cuts allow runoff to enter the bioswale, a minimum 2-inch drop in grade is required between the street and the bioswale. Curb cuts should be at least 18 inches wide and spaced 3–15 feet apart.

BIOSWALE WITH CHECK DAMS *Bioswales (described above) used on steep slopes with dams running perpendicular that slow stormwater runoff.*

Benefits: Check dams slow stormwater, helping to prevent erosion and allowing sediment to settle as it is filtered and conveyed or infiltrated within the bioswale.

Application: Check dams are recommended for bioswales with longitudinal slopes exceeding 5%.

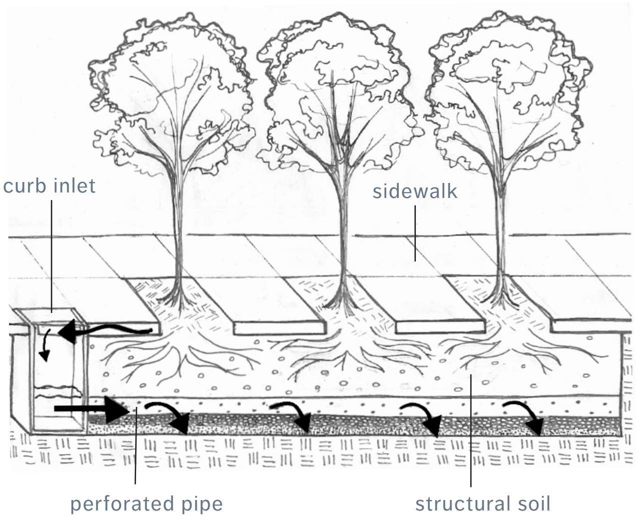
Construction Details: (see above) Check dams can be constructed using concrete, river rock, and sometimes logs.



FLOW-THROUGH PLANTER/TREE TRENCH *Long rectangular sidewalk planters with underground trenches, a series of connected cells filled with soil that receive stormwater runoff from the road. Runoff is treated as it moves through the cells before overflowing into gray infrastructure.*

Benefits: Tree trenches filter out sediment, trash, and pollutants from stormwater. They detain and, where possible, infiltrate water below grade, thus maximizing space above grade. Tree canopy intercepts and slows rainfall, and roots absorb stormwater and reduce pressure on the stormwater sewer system. Compared to conventional street trees, trees in tree trenches are often healthier because there is more room for root growth and space for air and water within soil.

Application: They are best suited for urban streets and sidewalks and near parks, retail, or commercial areas where space around trees is needed for pedestrian circulation.



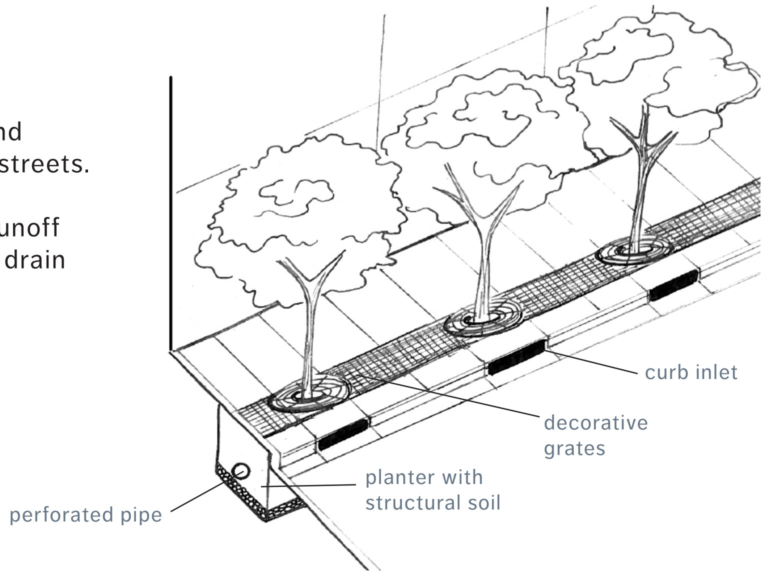
Construction Details: Tree trenches are filled with structural soil, layered over gravel, and planted with trees. An overflow drainage pipe connects to the stormwater sewer system. The planter is fed by curb-cut inlets along the road or direct connections to existing stormwater catchment basins. The size of the tree trench planter depends on the type of vegetation and the space available, however, they should be no less than 5x5 feet. Trees should be planted every 30' on center with soil media depth 3' and required drawdown time of 48 hours.

- Large Tree Trench (2 small deciduous trees): bottom surface area 420 sq ft.,
- Small Tree Trench (1 small deciduous tree): bottom surface area: 210 sq ft.

COVERED TREE TRENCH *Flow-through tree trench covered by permeable pavers or decorative grates that protect the planter from compaction and allow pedestrian access to streets.*

Benefits: The grates over the tree planters prevent soil compaction from foot traffic and allows pedestrian access to sidewalks and streets.

Application: They can be used to receive runoff from both curbs and sidewalks via inlets or drain runnels.

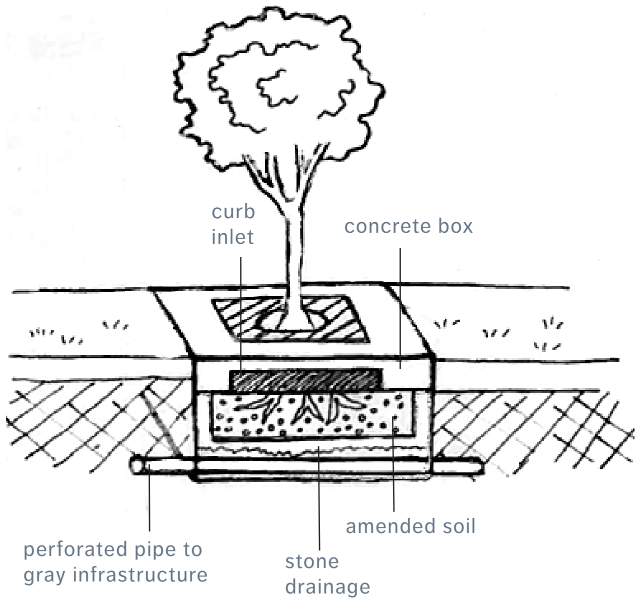


TREEBOX FILTER *Concrete bioretention container planted with a tree or shrub that intercepts and filters stormwater runoff.*

Benefits: Treebox filters remove large quantities of pollutants from stormwater. Mulch intercepts and separates particulates and contaminants at the ground level while soil microbes and plants remove pollutants through phytoremediation. Treebox filters improve the urban environment by greening neighborhoods, enhancing habitats, and reducing urban heat island effects.

Application: They are ideal for small urban spaces where bioretention gardens are not feasible. They can be planted with trees, shrubs, ornamental grasses, and flowers. Treebox filters can be used to treat, detain, and/or store rainwater for later use.

Construction Details: The concrete bioretention container is filled with engineered soil and planted with a tree or shrub. Excess runoff percolates through rocks into a perforated pipe connected to the gray infrastructure system, additional green infrastructure system, or surrounding soil. Omission of bottom slab allows stormwater to infiltrate where appropriate soils exist.



Limitations: Treebox filters hold a fairly small volume of stormwater (100 - 300 gallons), but because of their compact size, many can be installed in a single drainage area to intercept larger runoff volumes. They can be used where other types of bioretention may not be feasible. Additional runoff flows can be intercepted by adding storage volume beneath the filter box with an outlet control device.

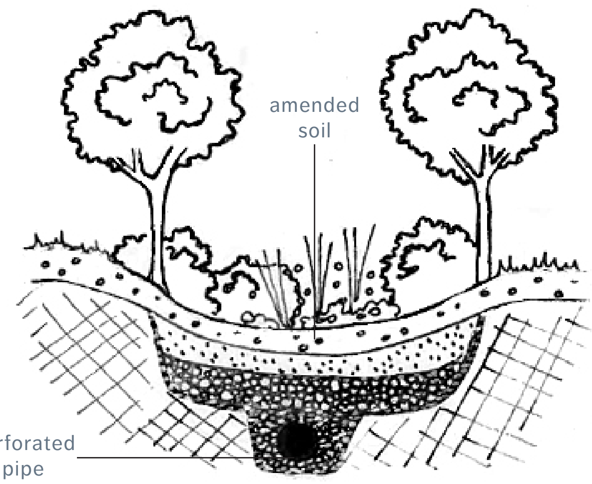
BIORETENTION/RAINGARDEN *Depression in the ground planted with vegetation and designed to intercept, temporarily hold, and filter stormwater runoff.*

Benefits: Raingardens are simple to install requiring a small degree of excavation. Both small raingardens and larger bioretention areas are effective at intercepting and treating runoff. Native vegetation provides habitat for wildlife, is hardy to local climate and requires less water. Trees, shrubs, and grasses sequester carbon.

Applications: Larger bioretention areas are ideal for subdivisions or commercial lots already cleared of vegetation. Raingardens can be installed on small sites, such as residential properties.

Construction Details:
Site bioretention areas on the lowest point of a property, upland from inlets and outfalls, and near the source of stormwater runoff. They should be at least 10 feet from structures. Avoid siting near walkways to reduce soil compaction. Spatial criteria depends on drainage area, intentional percent of runoff detention, and the design storm.

To discourage mosquito habitat, raingardens and other bioretention basins must only hold water temporarily, infiltrating all water over 12-72 hours. A percolation test should be conducted to ensure adequate drainage. If infiltration is not possible, and overflow should be installed. Soil should be excavated 6-12 inches to create a pooling area. Sand and compost amendments can be added to existing soil to ensure proper drainage.



Rocks at both inlets and overflow outlets reduce erosion and slow channeled water. Adding mulch around the base of plants aids in denitrification, particularly in areas with high nutrient levels (especially nitrates) such as residential areas.

Large bioretention basins that allow stormwater to infiltrate into the ground should not contain filter fabric. Those that receive runoff from pollution hotspots should use an impervious liner to prevent infiltration.

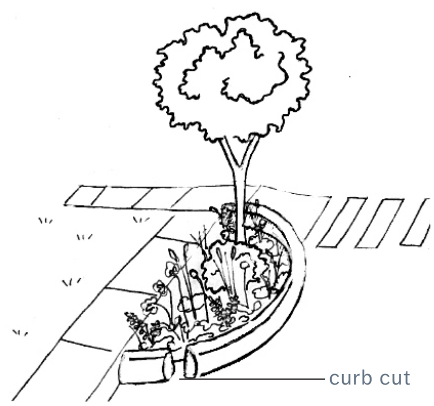
Limitations: In areas with a high water table, bioretention areas may be used to temporarily store stormwater, releasing it once peak runoff volumes and stress on the municipal storm system have subsided.

BUMP-OUT/CURB EXTENSIONS *Sidewalk extensions that provide quicker, safer crossings for pedestrians and intercept, store, and filter stormwater runoff.*

Benefits: Bump-outs and curb extensions contain plantings, street trees, and occasionally public benches. They can be placed at the end of a bioswale or along existing sidewalks. They enhance street safety by shortening the time pedestrians are exposed to oncoming traffic and by slowing vehicles.

Applications: They are well suited for downtown and residential areas and can be sited mid-block, at intersections, and/or at bus stops.

Construction Details: Bump-outs are often the size of an on-street parking space or approximately 2 feet narrower. Curb extensions vary depending on ROW width. Both are suited for areas that have less than 6% slope.

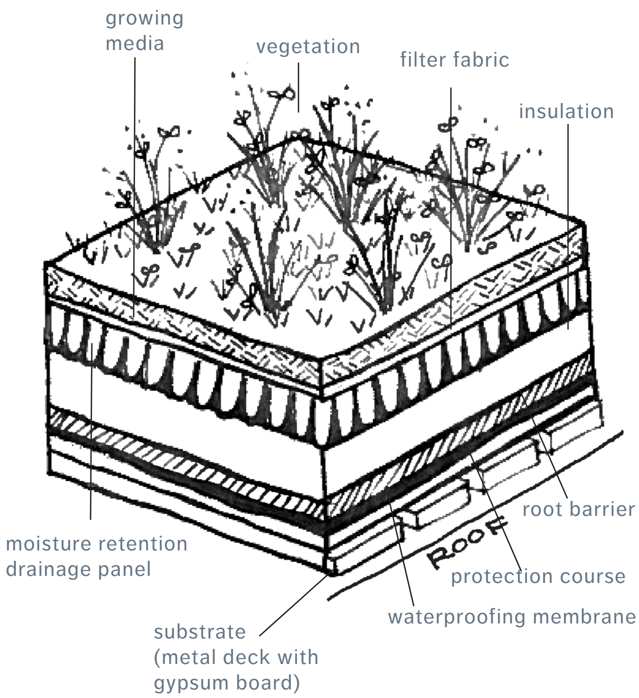


VEGETATED ROOF (GREEN ROOF): *Structurally-sound flat or slightly pitched roof-tops planted with vegetation that intercept, retain, and treat stormwater before it reaches the street.*

Benefits: Vegetated roofs are an effective strategy for capturing, filtering, and evapotranspiring rainwater where space is limited for ground-level interventions. Vegetation absorb pollutants through their roots and soil filters-out particulates, improving water quality of roof runoff. Vegetated roofs also provide wildlife habitat, create gathering spaces, and mitigate the urban heat island effect. They add insulation that helps regulate building temperatures, reducing demands for energy, soundproofing indoor spaces, and increasing the roof's lifetime by protecting it from UV damage.

Applications: They are best suited for flat roofs and can be applied on a range of structures including industrial, commercial, institutional, and residential. They can be used in combination with solar panels.

Construction Details: Roofs must be able to bear weight of materials and plantings. Water holding capacity varies by materials. Vegetative roofs require engineered mineral soil resistant to freezing and thawing, irrigation during establishment, and specific vegetation able to withstand rooftop microclimates. They are best suited for roofs with a slope of 0-30 degrees, minimum ¼"/ft., and 1"/ft. is ideal for drainage without slippage of materials. Extensive Vegetated Roofs are <6" in depth, whereas Intensive Vegetated Roofs are much deeper and can support larger vegetation.



Limitations: Extensive vegetative roofs are more economical than intensive vegetated roofs. Initial costs can be high but savings can be achieved over time through increased building efficiency and reducing impact on stormwater management system. Bioswales and raingardens may be more economical options where ground space exists.

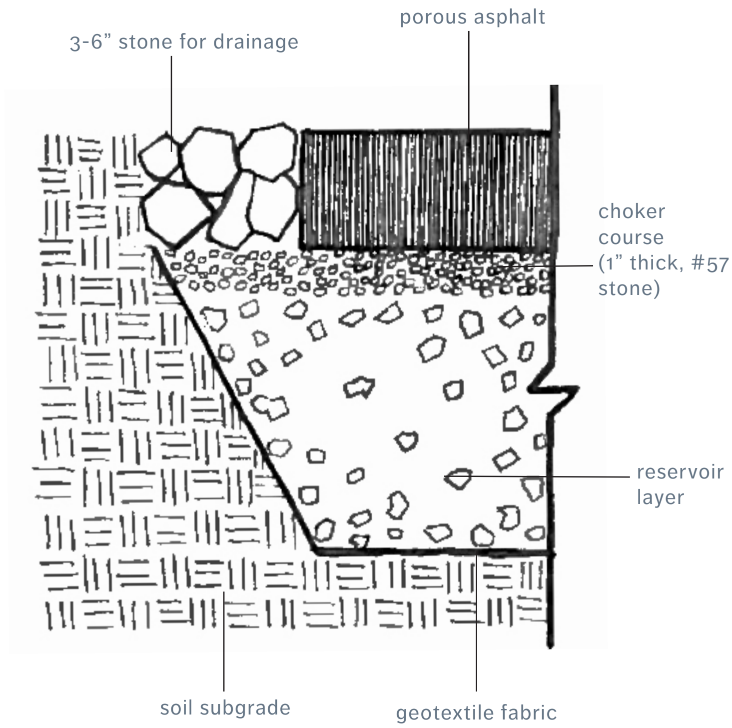
POROUS ASPHALT *Asphalt with larger "voids" that allow water to infiltrate into a layer of stone where stormwater is temporarily stored.*

Benefits: Porous asphalt does not require any additional space because it can replace conventional asphalt. It decreases runoff temperatures, improves water quality by removing pollutants through coarse sand filtration, and speeds snow/ice melt, reducing the need for salt and sand. It is also more durable, resulting in fewer potholes.

Application: Porous asphalt is well-suited for roads, parking lots, alleys, and sidewalks.

Construction details: There should be 3-5' vertical separation from seasonal high groundwater table. It is best suited for sites that are 3' above water table and 2' above bedrock with slopes <5%.

Limitations: Porous asphalt has higher upfront costs, but lasts twice as long as conventional asphalt and has equivalent savings when considering reduction in stormwater infrastructure costs.

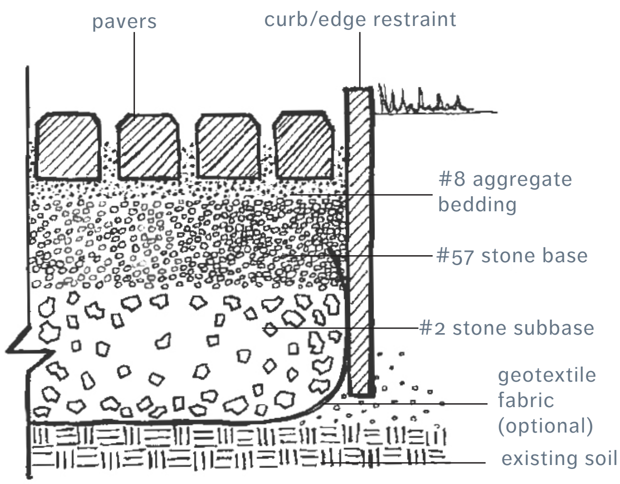


PERMEABLE PAVERS *Concrete bricks or pavers that allow stormwater runoff to permeate into an infiltration area below.*

Benefits: Permeable pavers can replace conventional pavement. By cooling water and trapping pollutants from vehicles, they can improve the quality of stormwater infiltrating into the ground. Also, they reduce the amount of water entering the municipal storm system which can relieve stress during peak runoff.

Applications: Permeable pavers are optimal on sidewalks, driveways, parking lanes, and streets where speed limits are low. Site where locations are 3 feet above the water table and 2 feet above bedrock and on slopes <5%.

Construction details: Water infiltrates through gaps between pavers and is stored in voids until filtering into the soil. Yearly maintenance includes removing debris and replenishing aggregate as needed. Pavers require less road salt than other types of paving in winter. Sand should not be used for deicing because it can block permeability.



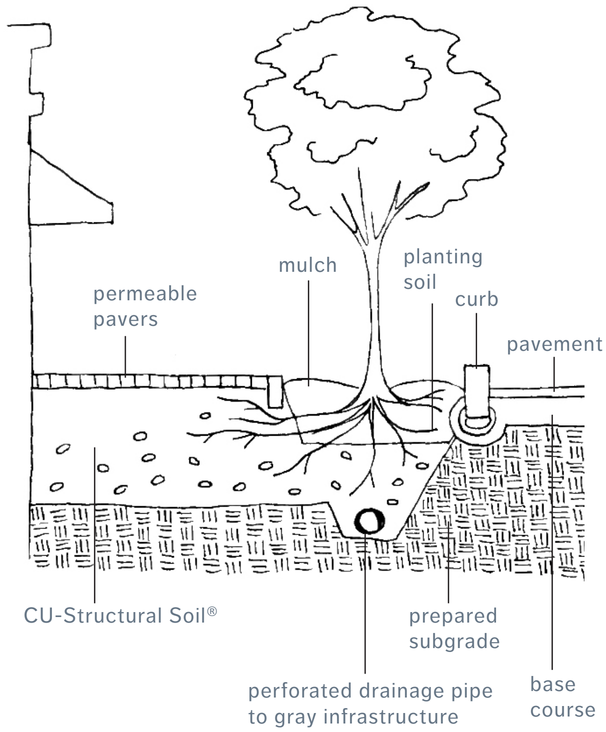
Areas with permeable pavers may be linked to underground stormwater chambers or other storage systems. They should have an infiltration rate: up to 50"/hr with maintenance, 3-4"/hr without maintenance.

STRUCTURAL SOIL/BREAKOUT: STRUCTURAL SOIL (CU-STRUCTURAL SOIL®) *Licensed, engineered soil mixture that creates a compacted, load-bearing lattice of angular stone with pockets of soil and air penetrable by tree roots.*

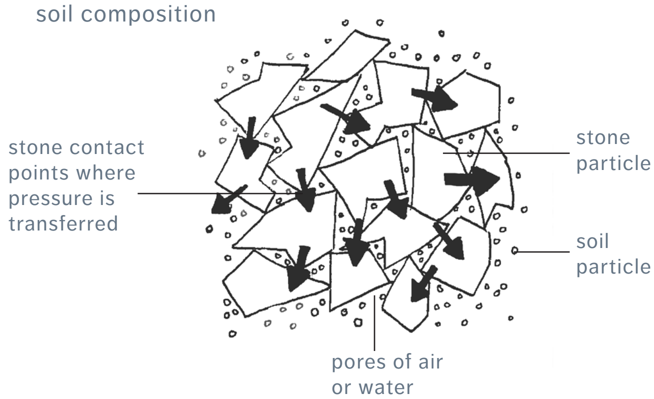
Benefits: Structural soil below sidewalks and/or in breakouts allows trees roots to grow more than they would in a conventional urban tree pit because they have more room and can penetrate the structural soil profile. This results in healthier urban street trees. Furthermore, trees can be planted closer together and roots can grow without heaving sidewalks. Stormwater interception and infiltration rates increase when structural soil is used in conjunction with permeable pavers and asphalt.

Applications: Structural soil works best in areas with minimal vehicle traffic such as pedestrian malls, sidewalks, and parking lanes, and in urban areas with large amounts of pavement and minimal soil.

Construction Details: Soil depths should be 24-36”. Trees should be planted that tolerate alkaline and well-drained soils. At the base of the planting area, a perforated drain should connect to the municipal storm system to prevent stormwater back-flow.



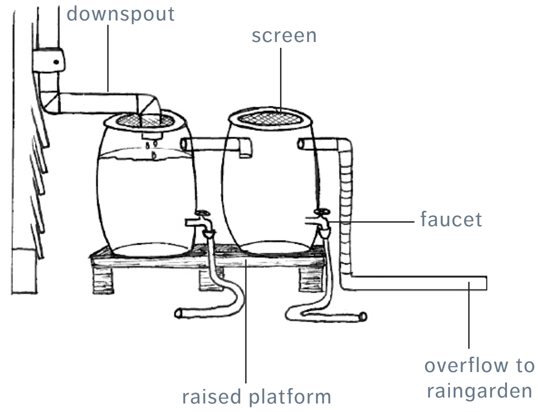
Detail of structural soil composition



CISTERNS AND RAIN BARRELS *Rainwater harvesting containers that can be attached to roof gutter downspouts that intercept, collect, and store stormwater runoff for later use.*

Benefits: Rainwater harvesting saves money and energy by decreasing demand for treated tap water. Rainwater harvesting effectively slows and diverts runoff before it reaches the catch basins, decreasing the impact of runoff on streams.

Applications: Best used on structures that have gutters. Harvested rainwater can be used for irrigating gardens, cleaning tools, washing cars, or a variety of other uses. For food-producing gardens, it is recommended that rainbarrels be used with metal roofs instead of asphalt shingles and a "first-flush" pollutant interception system be installed.

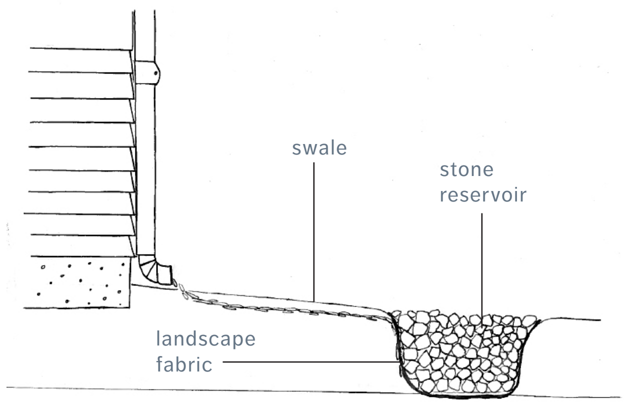


Construction Details: Rainwater from the gutter enters the rainbarrel which is covered by a screen, filtering leaves and debris and preventing mosquitoes from entering the reservoir. Tanks must be dark to prevent algae from growing. Rainbarrels have spigots near the bottom and can be elevated to increase water pressure using gravity. Rainbarrels must also have an overflow outlet which can be directed into a raingarden. Rainbarrels are often designed to hold 50 gallons of water but cisterns are available that can hold thousands of gallons. For greater runoff interception, multiple rainbarrels or cisterns can be linked. Rainbarrels can be installed under decks, along houses, or in unused spaces.

DRY WELL *Small excavated pits filled with gravel and stone that temporarily store stormwater runoff until it infiltrates into the soil.*

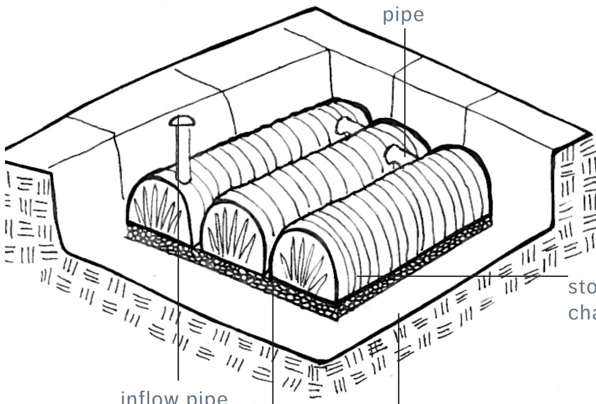
Benefits: Holding and infiltrating stormwater runoff reduces pressure on stormwater infrastructure, decreases flood impacts, improves water quality, and can recharge the groundwater supply.

Applications: Can be used in conjunction with or in place of a rainbarrel or raingarden to intercept overflow or runoff where percolation tests indicate soil conditions are suitable for infiltration.



Construction Details:
Line a small excavated pit with landscape fabric and fill with gravel and stone. Alternatively, use a prefabricated perforated hollow chamber buried in the ground. Convey rooftop runoff to dry well via downspouts connected to underground pipes, French drains, or grassy swales. Leaf guards should be installed on gutters so pipes will not clog. Should be sized appropriately to rooftop and storm volume, with a safe overflow design that will not damage neighboring properties.
Dry well should be located at least 10' from homes and 25' from any down-slope buildings.

STORMWATER CHAMBERS *Underground retention or detention of rainwater using buried prefabricated arch-shaped cisterns or perforated pipe and stone.*

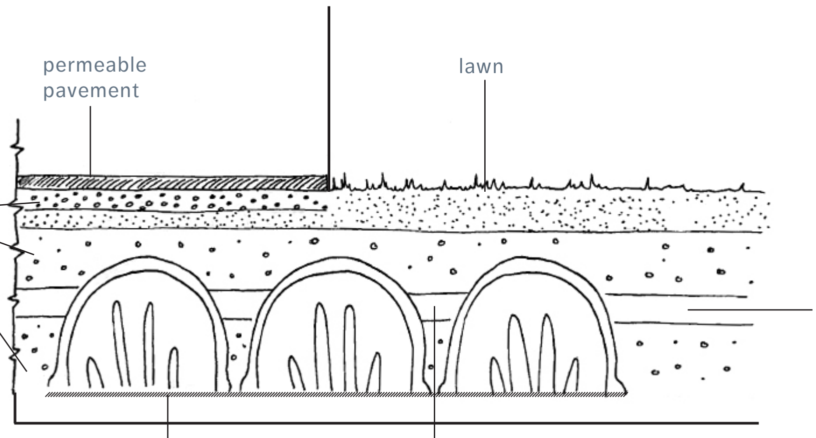


Benefits: Stormwater chambers decrease the volume of stormwater entering the municipal storm system during peak runoff, relieving stress and decreasing the likelihood of damage to these systems. They also enhance water quality by capturing sediment and removing pollutants, and recharge groundwater. When used in conveyance for ponds, stormwater chambers minimize algal blooms, sediment loading, and pond maintenance.

Applications: Stormwater chambers store stormwater runoff underground, below permeable parking, commercial land, parks, athletic fields, and urban green spaces. They are especially effective where there is not enough space for surface bioretention. Due to their ability to filter pollutants, installation should be considered near pollution hot spots.

Construction Details: Stormwater is channeled into bottomless underground chambers which function like a septic drain field, degrading nutrients and pollutants by percolating through filter fabric and stone into surrounding soil.

Water may be held temporarily during storm events and slowly released into aquifers, storm drains or waterways. Sizing of stormwater chambers depends on the supplier. Channels can be linked and stacked in alternating courses for maximum stormwater storage. Each chamber includes sediment traps that require periodic maintenance. Sediment may be removed by vacuum truck.



Plant List



LARGE TREES- OVER 30’ TALL

Common Name	Botanical Name	USDA Plant Hardiness Zone	Size (height x canopy width)	Evergreen (E)/ Deciduous (D)	Soil Type
Thornless Honeylocust	*Gleditsia triacanthos*	3-9	40-60’ x 20-40’	D	Well Drained
Eastern Red Cedar	*Juniperus virginiana*	2-9	30-50’ x 10-20’	E	Well Drained to Xeric
Swamp White Oak	*Quercus bicolor*	3-8	50-60’ x 50-60’	D	Wet to Well Drained
River Birch	*Betula nigra*	4-9	40-70’ x 40-60’	D	Moist to Well Drained
Hackberry	*Celtis occidentalis*	2-9	40-60’ x 40-60’	D	Moist to Well Drained
Black Gum, Swamp Tupelo	*Nyssa sylvatica*	4-9	30-50’ x 20-30’	D	Moist to Well Drained
Pin Oak	*Quercus palustris*	4-8	50-70’	D	Moist to Well Drained
Kentucky Coffeetree	*Gymnocladus dioica*	3-8	60-80 x 40-55’	D	Moist to Well Drained

SMALL TREES - 10-30’ TALL

Common Name	Botanical Name	USDA Plant Hardiness Zone	Size (height x canopy width)	Evergreen (E)/ Deciduous (D)	Soil Type
American Holly	*Ilex opaca*	5-9	20-30’ x 15-20’	E	Moist to Well Drained
Gray Alder	*Alnus incana*	2-6	15-30’ x 10-20’	D	Moist to Well Drained
Sweet Bay	*Magnolia virginiana*	5-10	20-30’ x 10-20’	Semi-E	Moist to Well Drained
Sourwood	*Oxydendrum arboreum*	5-9	25-30’ x 15-20’	D	Well Drained
Eastern Redbud	*Cercis canadensis*	4-9	20-30’ x 25-35	D	Well Drained

Trees, shrubs, and herbaceous plants are useful for slowing, cooling, and filtering stormwater. The following plant list outlines native species hardy to Mystic, Connecticut's coastal USDA hardiness zone 6b, that are able to withstand periods of stormwater inundation. These can be planted in bioretention areas, bioswales, and along streets. Plants were chosen based on salt tolerance, ability to support pollinator habitats, and use in previous phytoremediation research (Kennen pp. 74-85, 266-267). Plant sizes, bloom times, soil moisture and sun exposure were also considered. A planting plan should be tailored to each site's specific conditions.

Exposure	Salt Tolerance	Bioretention	Drought Tolerant	Bloom Time	Phytoremediation Potential
Sun	High	Yes	Yes	May-Jun	Yes
Sun	High	Yes	Yes	---	Yes
Sun	Moderate	Yes	Yes	---	---
Sun	Moderate	Yes	Yes	---	Yes
Sun-Part Shade	Moderate	Yes	Yes	---	---
Sun	Moderate	Yes	Yes	Apr-Jun	---
Sun	Mild	Yes	No	---	---
Sun	Moderate	Yes	Yes	---	Yes

Exposure	Salt Tolerance	Bioretention	Drought Tolerant	Bloom Time	Phytoremediation Potential
Sun to Part Shade	Moderate	Yes	Yes	May	---
Sun	High	Yes	Moderate	March	Yes
Sun to Part Shade	Moderate	Yes	Yes	May-June	---
Sun to Part Shade	Moderate	Yes	Moderate	June-July	---
Sun to Part Shade	No	Yes	Yes	Mar-Apr	Yes

SHRUBS

Common Name	Botanical Name	USDA Plant Hardiness Zone	Size (height x width)	Evergreen (E)/ Deciduous (D)	Soil Type
Elderberry	*Sambucus nigra*	5-7	6-8'	D	Moist to Well Drained
Red Chokeberry	*Aronia arbutifolia*	4-9	6-10' x 3-5'	D	Moist to Well Drained
Red Osier Dogwood	*Cornus sericea*	3-7	6-8' x 5-8'	D	Moist to Well Drained
Sweet Pepperbush	*Clethra alnifolia*	3-9	4-8' x 3-6'	D	Moist to Well Drained
Dwarf Sweet Pepperbush	*Clethra alnifolia* 'Hummingbird', 'White Doves', 'Sixteen Candles'	3-9	2-3' x 4-6'	D	Moist to Well Drained
Inkberry Holly	*Ilex glabra*	4-9	5-8' x 5-8'	E	Moist to Well Drained
Adam's Needle Yucca	*Yucca filamentosa*	5-10	2-4' x 2-4'	E	Well Drained to Xeric

GRASSES

Common Name	Botanical Name	USDA Plant Hardiness Zone	Size (height x width)	Soil Type
Muhly Grass	*Muhlenbergia capillaris*	5-9	3'x3'	Well Drained to Xeric
Atlantic Coastal Switchgrass	*Panicum amarum*	2-9	3' x 2'	Well Drained to Xeric
Prairie Cordgrass	*Spartina pectinata*	4-9	to 7' tall in flower	Wet to Xeric
Switchgrass	*Panicum virgatum*	5-9	4-8' x 2-4'	Moist to Well Drained
Little Bluestem	*Schizachyrium scoparium*	3-9	2-4' x 1.5-2'	Moist to Well Drained
Bottlebrush Grass	*Elymus hystrix*	4-9	3-5' x 1-2'	Moist to Well Drained

GROUNDCOVERS

Common Name	Botanical Name	USDA Plant Hardiness Zone	Size (height x width)	Soil Type
Beach Wormwood	*Artemisia stelleriana*	Zones 3-9	6"-12"	Well Drained to Xeric
Moss Pinks	*Phlox subulata*	Zones 3-9	0.5' x 2'	Well Drained to Xeric
Creeping Juniper	*Juniperus horizontalis*	Zones 3-9	10"-12" x 5-8'	Well Drained to Xeric

Exposure	Salt Tolerance	Bioretention	Drought Tolerant	Bloom Time	Phytoremediation Potential
Sun to Part Shade	Highly	Yes	Yes	Jun-Jul	Yes
Sun to Part Shade	Moderate	Yes	Yes	May-Jun	Yes
Sun to Part Shade	Moderate	Yes	Yes	May-Jun	Yes
Sun to Part Shade	Moderate	Yes	Low	Jul-Aug	Yes
Sun to Part Shade	Moderate	Yes	Low	Jul-Aug	Yes
Sun to Light Shade	Moderate	Yes	Yes	---	---
Sun	Moderate	Yes	Yes	May-Jun	---

Exposure	Salt Tolerance	Bioretention	Drought Tolerant	Bloom Time	Phytoremediation Potential
Full Sun	High	Yes	Yes	Sept-Nov	---
Full Sun	High	Yes	Yes	Sept-Feb	Yes
Full Sun	High	Yes	Yes	Jul-Aug	Yes
Full Sun	Moderate	Yes	Yes	July-Feb	Yes
Full Sun	Moderate	Yes	Yes	Aug-Feb	Yes
Part Shade to Shade	No	Yes	Yes	Sept-Oct	Yes

Exposure	Salt Tolerance	Bioretention	Drought Tolerant	Bloom Time
Full Sun	Moderate	Yes	Yes	---
Full Sun	No	Yes	Yes	Mar-May
Full Sun	Moderate	Yes	Yes	---

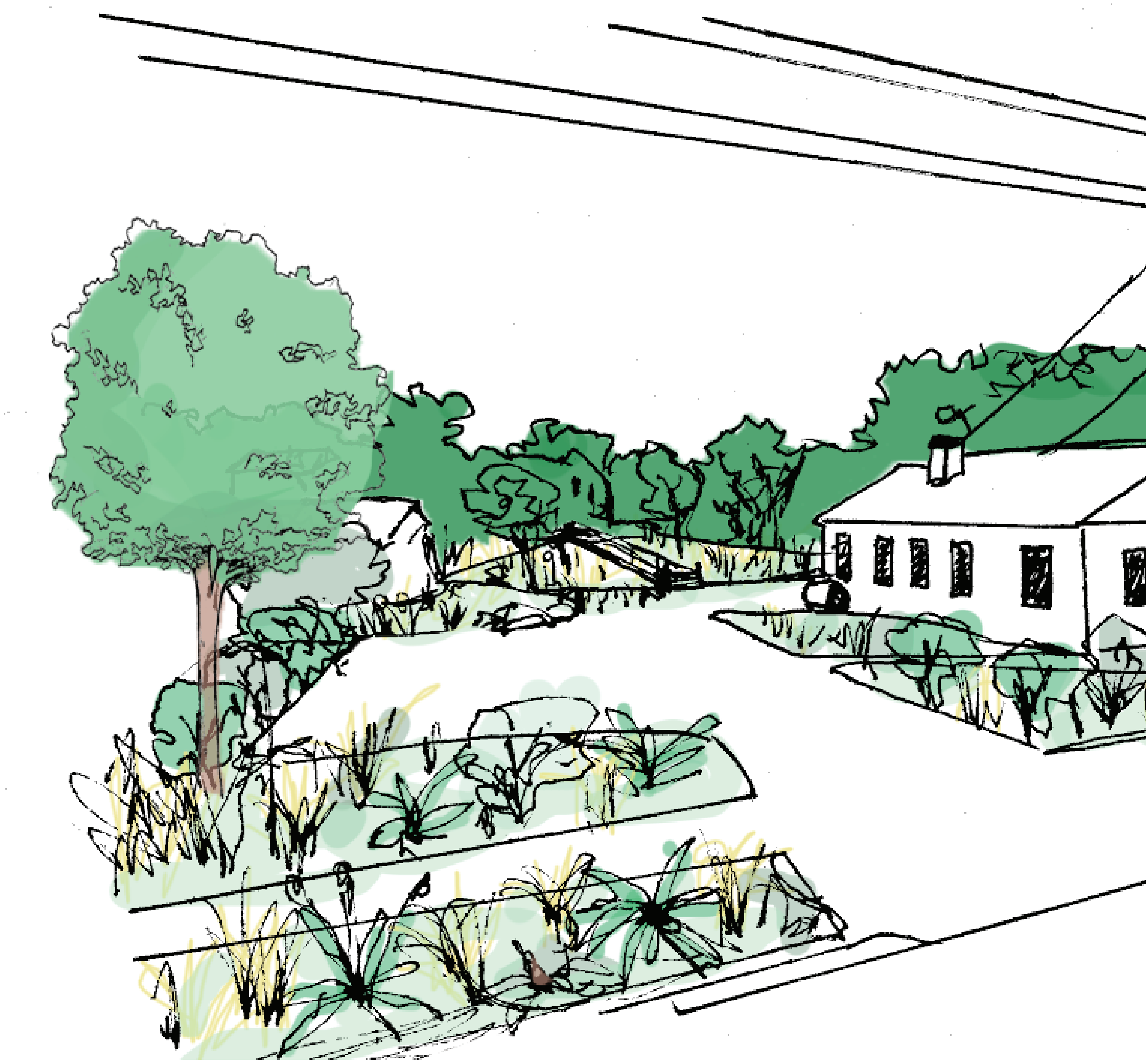
PERENNIALS

Common Name	Botanical Name	USDA Plant Hardiness Zone	Size (height x width)	Soil Type
Blanket Flower	*Gaillardia pulchella*	2-11	1-2' x 1-2'	Well Drained to Xeric
Smooth Blue Aster	*Aster laevis*	4-8	2-3' x 2-4'	Well Drained to Xeric
Prickly Pear Cactus	*Oputia humifusa*	4-9	1-2' x 2-3'	Well Drained to Xeric
Butterfly Weed	*Asclepias tuberosa*	3-9	2-3' x 2-3'	Well Drained to Xeric
Seashore Mallow	*Kosteletzkya virginica*	6-9	4-6' x 3-4'	Moist to Well Drained
Purple Coneflower	*Echinacea purpurea*	3-8	3-5' x 2-4'	Well Drained
Hardy Hibiscus	*Hibiscus moscheutos, Hibiscus coccineus, Hibiscus* hybrids	5-9	4-6' x 4-6'	Moist to Well Drained
Autumn Sage	*Salvia greggii, Salvia microphylla*	6-9	2-4' x 2-4'	Well Drained
Black-eyed Susan	*Rudbeckia fulgida* 'Goldsturm'	3-9	2' x 2'	Moist to Well Drained
Arkansas Blue Star	*Amsonia hubrichtii*	5-8	2-3'	Moist to Well Drained
False Wild Indigo	*Baptisia australis*	3-9	3-4'	Moist to Well Drained
Wine Cups	*Callirhoe involucrata*	4-8	1' x 3'	Moist to Well Drained
Threadleaf Coreopsis	*Coreopsis verticillata*	3-9	2.5-3'	Moist to Xeric
Gaura	*Gaura lindheimeri*	5-9	1' x 3'	Well Drained

	Exposure	Salt Tolerance	Bioretention	Drought Tolerant	Bloom Time
	Sun	High	Yes	Yes	Jun-frost
	Sun to Part Shade	Moderate	Yes	Yes	Aug-Oct
	Sun	High	Yes	Yes	Jun-Jul
	Sun	Moderate	Yes	Yes	Jun-Aug
	Sun to Part Shade	Moderate	Yes	Low	Jun-Sept
	Sun to Part Shade	Slight	Yes	Yes	Jun-Aug
	Sun to Light Shade	Slight	Yes	Moderate	Jul-Sept
	Sun to Light Shade	Slight	Yes	Yes	Jun-Oct
	Sun to Light Shade	Slight	Yes	Yes	May-frost
	Full Sun	No	Yes	Yes	Jun-Sept
	Sun to Part Shade	No	Yes	Yes	May-Jun
	Full Sun	No	Yes	Yes	May-Jun
	Full Sun	No	Yes	Yes	Jun-Sept
	Full Sun	No	Yes	Yes	Aug-Oct

Non-Residential

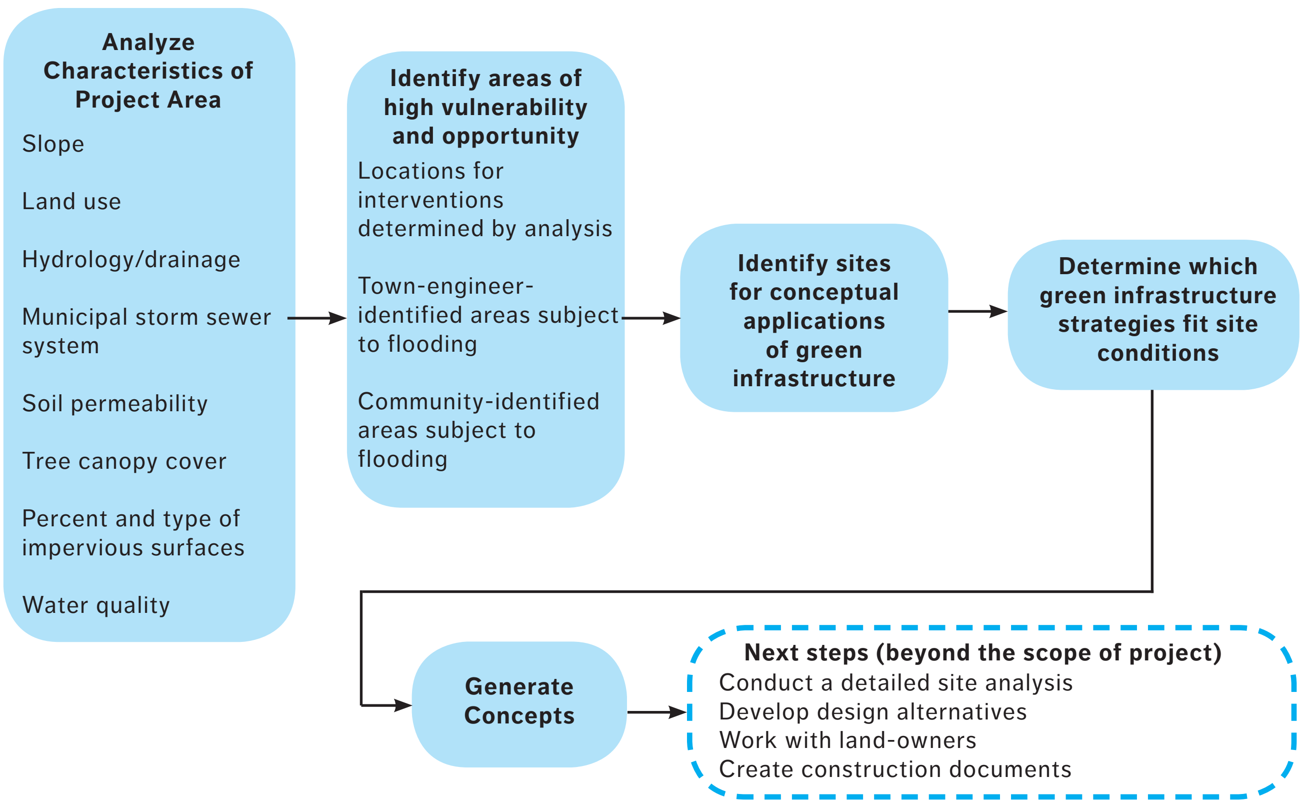
GREEN INFRASTRUCTURE STRATEGIES FOR COMMERCIAL, INDUSTRIAL, AND PUBLIC SPACES.



Bioretention area at the University of Wisconsin *Photo Credit: Aaron Volkening*

NON-RESIDENTIAL DESIGN PROCESS

A four-step design process was developed in order to identify sites and potential design interventions. Using GIS data from CT DEEP, CT ECO, and the Town of Stonington, the Conway team studied existing site conditions including hydrology, topography, land use, water quality, impervious surfaces, and the existing municipal storm sewer system. Stormwater problem areas were also identified at the community meeting and by the town engineer. Green infrastructure techniques were evaluated based on their spatial constraints and ability to filter stormwater runoff, create habitats, and complement the character of the village. More extensive site analysis will be needed before any designs are implemented.

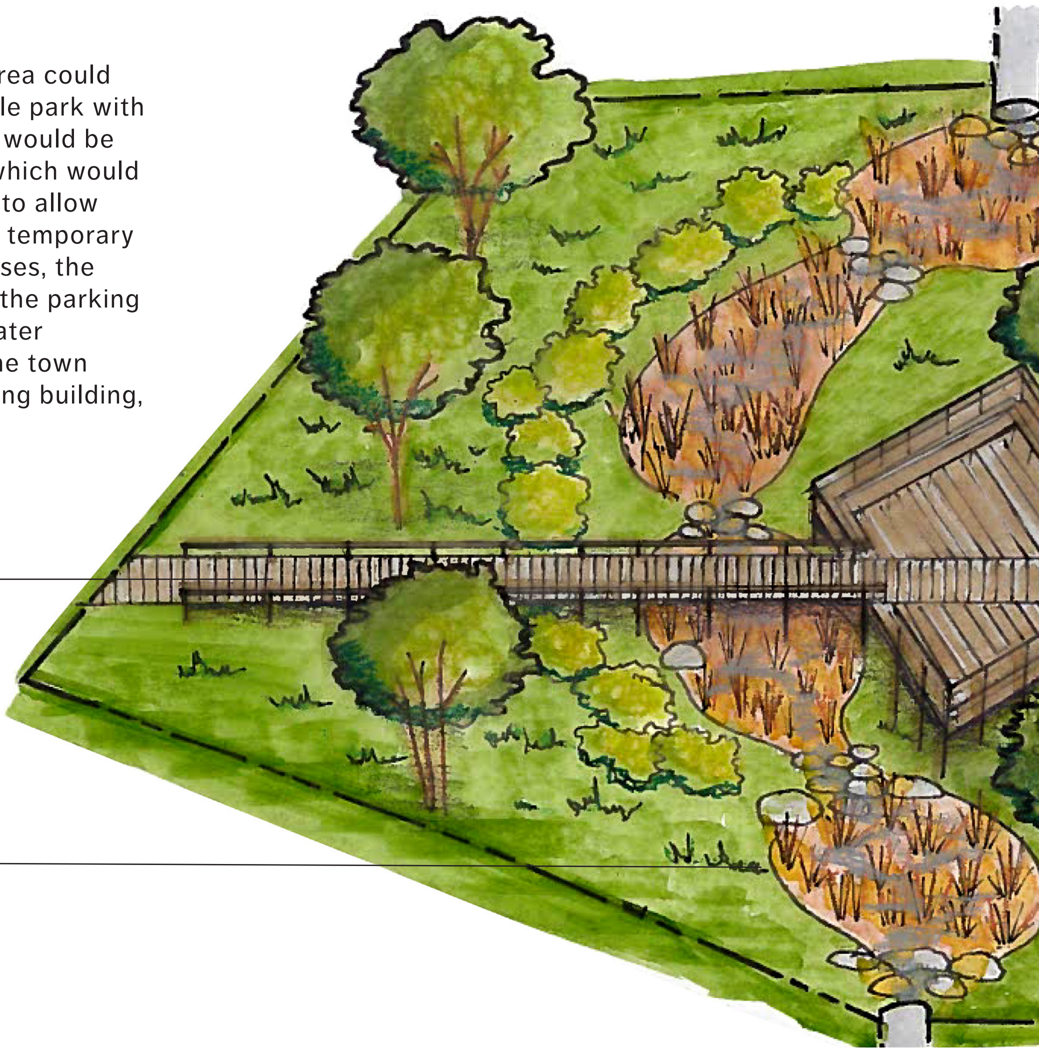


Non-Residential Municipal Site: Fourth District Voting Hall

The former Fourth District Voting Hall is a 0.6-acre site owned by the town that is currently used only for occasional meetings and storage. This is a low-lying spot in a residential area where runoff pools from surrounding properties and the high-tide backflow from the stormwater catchment basin in the drainageway underlying the site. It was identified by the town civil engineer as one of several flood-prone sites in Mystic that currently has no official use and would be ideal for green infrastructure intervention. This site is large enough to accommodate several interventions and amenities designed to address flooding issues. Its downtown location makes it a potentially appropriate space for providing additional parking, which is a concern in the community during the tourist season.

In response to these conditions, this area could be potentially redesigned as a floodable park with a permeable parking lot. The property would be excavated and reshaped into a basin which would hold water after the culvert is opened to allow for controlled flooding of the park and temporary bioretention. After the peak storm passes, the park and stormwater chambers under the parking lot could drain into the town's stormwater management infrastructure. Should the town decide to keep and renovate the existing building, the same design principles can apply to the rest of the site.

Low-lying flood-prone sites exist throughout downtown Mystic. Designing these spaces to receive water and flood in a controlled manner will help address nuisance flooding on surrounding streets and properties. To prevent nuisance flooding, interventions in upland properties will help prevent runoff from accumulating in low-lying areas. Existing parks throughout the village can incorporate stormwater remediation and temporary storage during peak flood events using stormwater chambers and bioretention gardens. All impermeable parking areas can be repaved with permeable asphalt over structural soil and surrounded by bioswales for runoff treatment.



The boardwalk and platform area could include educational interpretive signs and provide opportunities for wildlife habitat observation.

Bioswales and gardens of trees, shrubs, grasses, and marsh areas would provide habitat and opportunity to absorb and treat stormwater. *(Toolbox, pp. 49 and 52)*

Fourth District Voting Hall (used for storage by the town of Stonington)

Flooding from an Extremely High Tide Coupled with Heavy Precipitation

Porous asphalt allows stormwater to infiltrate into the ground. *(Toolbox, p. 54)*

Underground stormwater storage chambers can be installed below the permeable parking lot and temporarily hold stormwater as it percolates through the parking area. *(Toolbox, p. 57)*

Case Study: Permeable Paving Materials and Bioretention in a Parking Lot, *see p. 75*

Non-Residential Commercial Site: Washington Street Bioremediation Pocket Park

Washington Street is a low-lying road subject to frequent flooding from both stormwater runoff and stormwater catchment drains backflowing from outfalls in nearby water bodies. Analyzing topography and runoff stream flow channels shows that the road forms a temporary stream during heavy rain events. Washington Street has multiple stormwater catchment basins with outfalls into the marsh and harbor. Because this is also a hotspot, flooding is of additional concern. It was identified by the community and the town engineer as a particularly vulnerable area and it sits within a high concentration of other pollution hotspots.

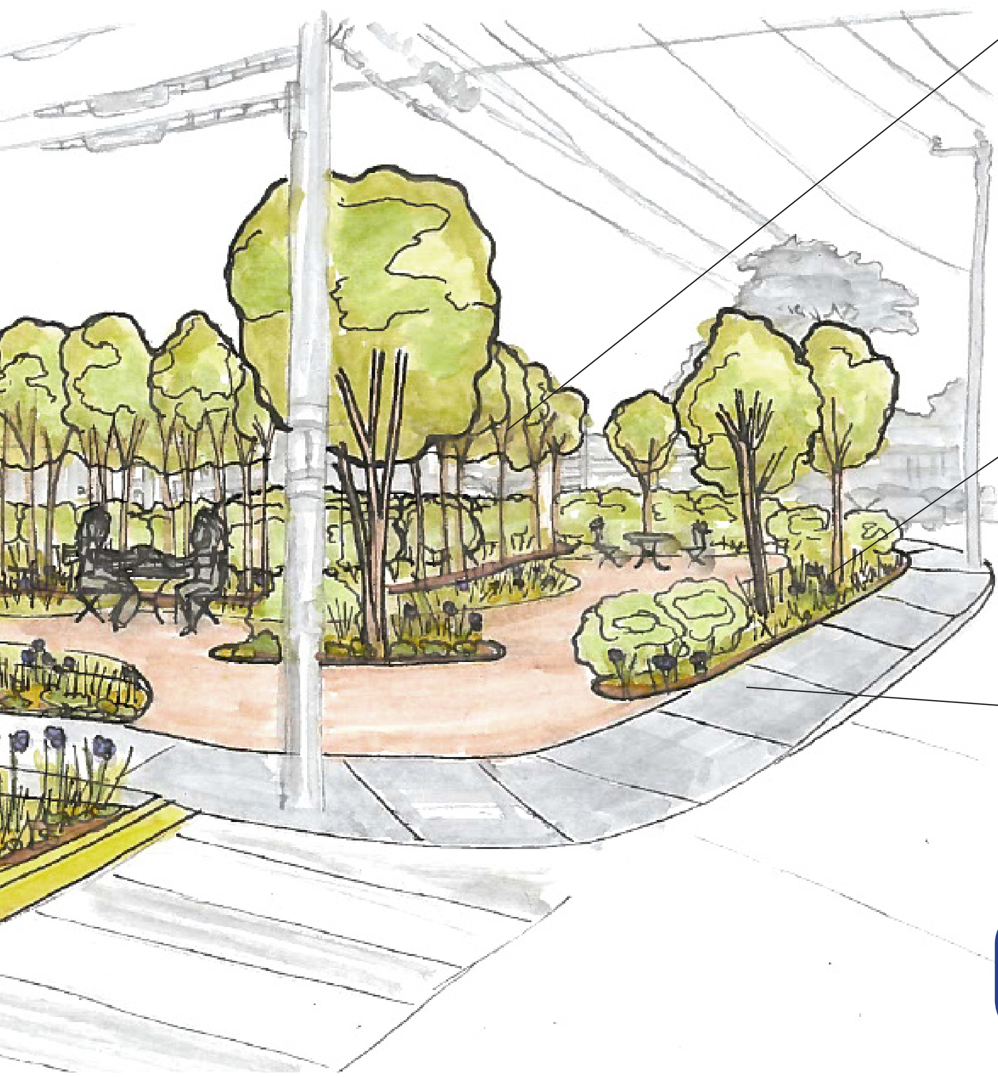
One of the pollution hotspots along Washington Street is a gas station with an adjacent vacant lot. This lot is located along a highly visible section of Main Street or Route 1, a well-traveled thoroughfare into downtown that was identified by the Stonington *Climate Resiliency Plan* as a potential "Green Corridor." This previously developed lot is currently a mowed field that is primarily flat with a low sidewalk around the perimeter. The neighborhood is a mixture of residential and commercial. While currently, the owner of the vacant property has development plans for this site, the following conceptual design provides a model how green infrastructure can be applied to contaminated undeveloped lots in Mystic.

Designing vacant lots into bioremediation parks throughout Mystic could add much needed community green space for gatherings and recreation, and complement the oceanside character of the community. Addressing climate change through interpretive green infrastructure in public spaces can help visitors and residents understand how these green spaces can help increase climate resilience. These interventions also provide initial stormwater treatment before runoff reaches a storm sewer system. There are several gas stations in the downtown area where polluted runoff could be intercepted and filtered by green infrastructure.

Interpretive signs can educate residents and tourists about how elements of the design intercept stormwater runoff, mitigate flooding, and treat pollutants. Signs can also suggest how these techniques might be replicated on other sites.

Vacant Lot on the corner of Washington Street and Route 1

Smaller interventions like filter strips and bioswales can be incorporated into the landscaping surrounding gas stations. Impervious surfaces such as gas station driveways and parking areas can be graded toward these smaller bioretention areas. Stormwater catch basins and drains could be installed in gas station pavement to direct runoff to green infrastructure systems depending on slope and how much stormwater flows on site. *(Toolbox, p. 49)*



Tree trench treatment cells and an interception hedgerow can incorporate trees and shrubs in systems designed to break down pollutants; their canopy can filter air. *(Toolbox, p. 50)*

Roads and gas station paving can be regraded to drain into curbcuts, inlets, and runnels that convey polluted runoff into bioswales and rain gardens. *(Toolbox, p. 49 and 52)*

Case Study: Phytoremediation Treatment of Hydrocarbons, *see p. 75*

Non-Residential Public Site: Mystic River Park

Mystic River Park was identified by the community as an opportunity for outreach and education about green infrastructure. Mystic River Park is important to the community because it is one of the few public spaces along the waterfront. Its boardwalk is a popular tourist destination for those leisurely enjoying the waterfront. The park often hosts large summer festivals, public events, and free concerts during the tourist season.

In this concept design, Mystic River Park retains its open grassy field as an important public riverfront gathering space. At the same time, a combination of several green infrastructure techniques filter and temporarily hold runoff along its perimeter.

The park is bordered by bioswales planted with native grasses and herbaceous perennial flowers endemic to coastal regions to help retain the historic character of Mystic. These bioswales have check dams to slow runoff while shrubs, grasses, and herbaceous perennials help to absorb stormwater while filtering sediment and pollutants.
(Toolbox p 49.)

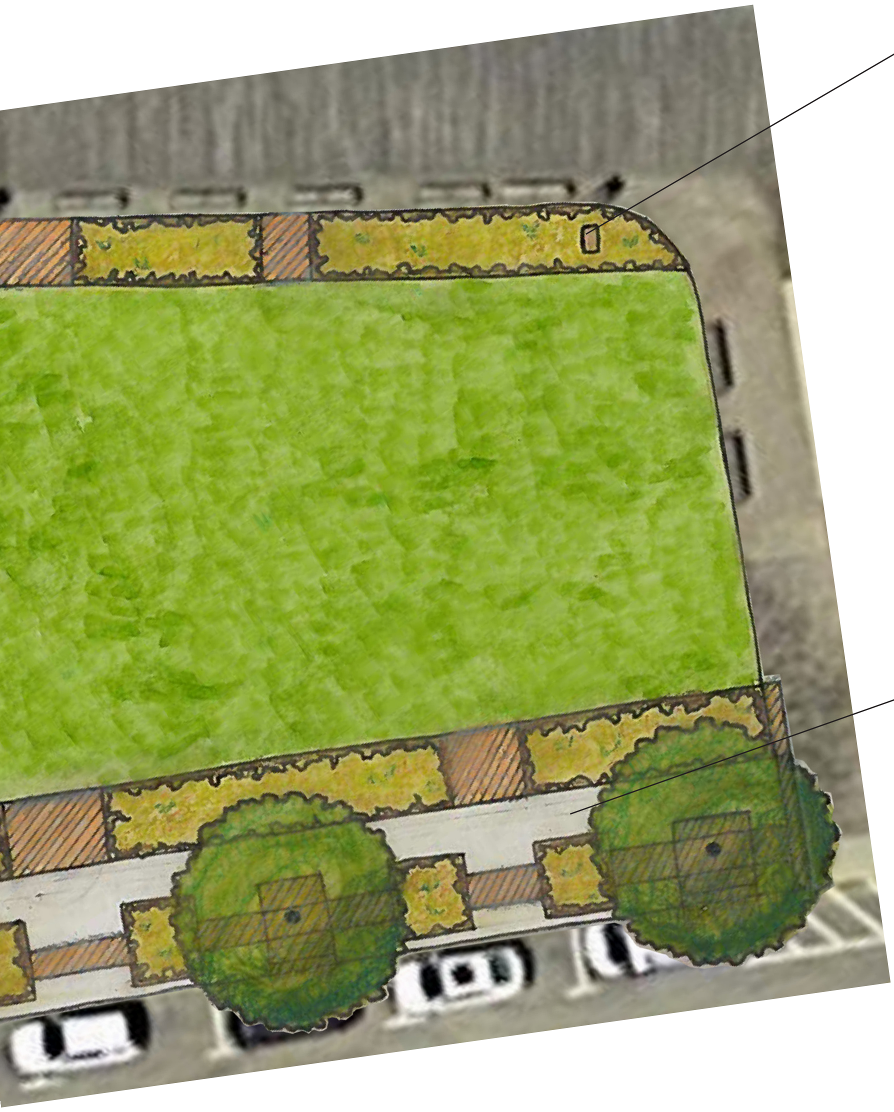
The park lawn is graded to drain into the bioswales that surround the park.

Stormwater treatment begins at Cottrell Street, where runoff is directed into catchment basins linked below ground to the tree trench and rain gardens for initial filtering. Runoff overflow from the tree trench percolates into an underground perforated pipe that channels excess stormwater into perimeter bioswales. *(Toolbox, p. 49)*

The tree trench and bioswales have crossings covered with a decorative grate to maintain pedestrian access between vehicles, gardens, and boardwalk. *(Toolbox, pp. 49 and 50)*

Mystic River Park and adjacent boardwalk

Educational signs located throughout gardens within the park interpret the design and functions of green infrastructure for residents and tourists.



A widened sidewalk along Cottrell Street in front of Mystic River Park includes space for gardens and street trees along the road that invite pedestrians into the park lawn and boardwalk. The sidewalk of permeable pavers is installed over structural soil to accept more runoff and allow for root expansion, supporting tree health and longevity. *(Toolbox, pp. 51 and 54)*

Case Study: Partnering with Colleges for Community Learning, *see p. 75*

LIMITATIONS

For sites with a high water table, infiltrating stormwater may not be possible. In this case, green infrastructure needs to be designed to slow, filter, temporarily hold and later release stormwater into the surrounding water bodies after the peak storm subsides. Bioswales and raingardens temporarily hold stormwater in smaller storm events where it can evaporate or be absorbed by vegetation. In large storm events, runoff is conveyed through these bioswales where it is slowed and filtered. The pretreated stormwater then overflows from the bioswales through drains into existing grey infrastructure and outfalls into surrounding surface waters.

In the case that there is sufficient percolation and depth to the water table, underground stormwater storage chambers can be installed below the grass in the center of the park. A series of underground chambers allow for large amounts of water storage without having to create a large bioretention area in the park, temporarily holding the pretreated runoff underground where it infiltrates through a permeable filter into surrounding soil or is released into waterways once the peak storm subsides.

Not far from Mystic River Park is a small playground that may also be an opportunity for public education. Some of these conceptual designs can be implemented on larger institutional sites like schoolyards or hospital grounds. Any implementation of green infrastructure should be preceded by extensive site analysis including and not limited to identifying soil types and percolation rates, area stormwater volume calculations for various storm intensities, runoff simulations, and determining the depth to water table to determine the applicability of infiltration designs.

CASE STUDIES

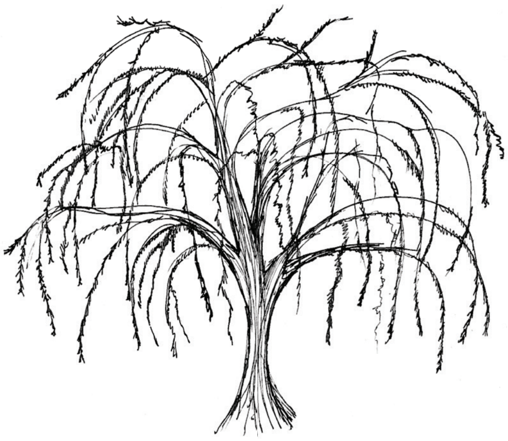
Permeable Paving and Bioretention in a Parking Lot

Case Study: Silver Lake Beach Parking Lot (Commonwealth of Massachusetts)

In 2006, Silverlake Beach in Wilmington, MA constructed an LID demonstration project using a permeable parking lot and vegetated filter strips to treat non-point source pollution and increase infiltration of stormwater. It was one of four similar projects through the Ipswitch River Watershed Association, funded by a grant from the EPA. Water quality monitoring from the U.S. Geological Survey between 2005 and 2007 showed a significant decrease in bacterial and nutrient related beach closures, with no indication of groundwater impairment. Infiltration rates met or exceeded expectations, with average infiltration rates of 69” per hour for porous asphalt and 49” per hour for porous pavers. This project was part of a community education campaign, where an interpretive sign was displayed in the parking lot and brochures about residential actions to protect the watershed were mailed to residents. Initial maintenance was contracted to the installer, but after 3 years was assumed by the Wilmington Department of Transportation.

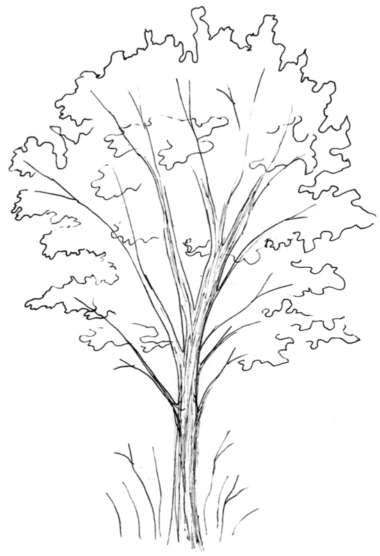
Photo Credit: Mass.gov/ GeoSyntec

PLANTS FOR PHYTOREMEDIATION



Black willow
Salix nigra

Cattail
Typha latifolia



Eastern cottonwood
Populus deloides

Phytoremediation Treatment of Hydrocarbons

Case Study: Gasoline line and adjacent wetland near Athens, GA
(O'Neil, et al.)

Phytoremediation refers to the use of plants, and soil microbes to clean soil and water contaminated with metals, petroleum, chlorinated solvents, volatile organic compounds (VOCs), bacteria, and nutrients (phosphorous and nitrogen). In 1997, a gasoline spill occurred in a coastal area near Athens, GA. Preliminary efforts to use phytoremediation with trees failed, but in 2001, PLANTECO environmental consultants upgraded the system to include compost to increase soil microbes, irrigation from a nearby creek, and wetland plants such as cottonwood poplar, black willow, cattail, native sedge, arrowhead and bulrush. The study found that compost increased health of plants and soil microbes, herbaceous plants effectively treated shallow soils, and deep-rooted trees remediated deeper soils. They also found that plants are most effective at absorbing pollutants and water during the growing season.

Partnering with Colleges for Community Projects

Case Study: Communities in Hartford, CT
(Hartline)

As part of her course, "Global Perspectives in Biodiversity and Conservation," Amber Pitt, Professor of Environmental Science and Biology at Trinity College, required a real-world research component, matching 48 student volunteers with community partners. They completed projects across Hartford such as cleaning-up rivers, planting pollinator gardens, and managing stormwater with rain gardens. Students then shared their experiences in a research poster fair. With community leadership and clear project goals, partnering with area colleges can be mutually beneficial for students and communities. It provides real-world experiences for students and spurrs future collaborations within the community. It also promotes an exchange of knowledge through educational publications and presentations.

Residential

GREEN INFRASTRUCTURE STRATEGIES AND MUNICIPAL RECOMMENDATIONS FOR STORMWATER MANAGEMENT ON SINGLE-FAMILY RESIDENTIAL PROPERTIES.

Stormwater Reduction on Residential Properties

WHY RESIDENTIAL?

Small-scale interventions play a vital role in slowing, reducing, and filtering stormwater runoff, especially when efforts are made across multiple sites. This has the potential to be particularly effective within the project area because 35% of land in Stonington is used as single-family, residential. Although 10% of the total project area is impervious, the percentage increases to an average of 12% impervious cover on residential properties. While some runoff from impervious surfaces does infiltrate into the ground, most of it enters the municipal storm system. This indicates that residential properties contribute significantly to the total amount of stormwater that is discharged into nearby water bodies and/or causes flooding. It presents an opportunity to work with private property owners to implement techniques for stormwater treatment and reduction.

Although large-scale stormwater management techniques are important for reducing the negative impacts of stormwater, even small-scale strategies that treat the first inch of rain can reduce flooding and improve watershed health. The average residential parcel within the project area is approximately 20,000 square feet, of which approximately 2,400 square feet is typically impervious. The majority of impervious surfaces comprise roofs and driveways which have roughly the same runoff coefficient of between .8 and .95 (Lancaster, 45). This means that between 80% and 95% of the water that hits these surfaces will runoff the surface rather than infiltrate into the ground.

(area cu.in. /231) x 1" rainfall x runoff coefficient

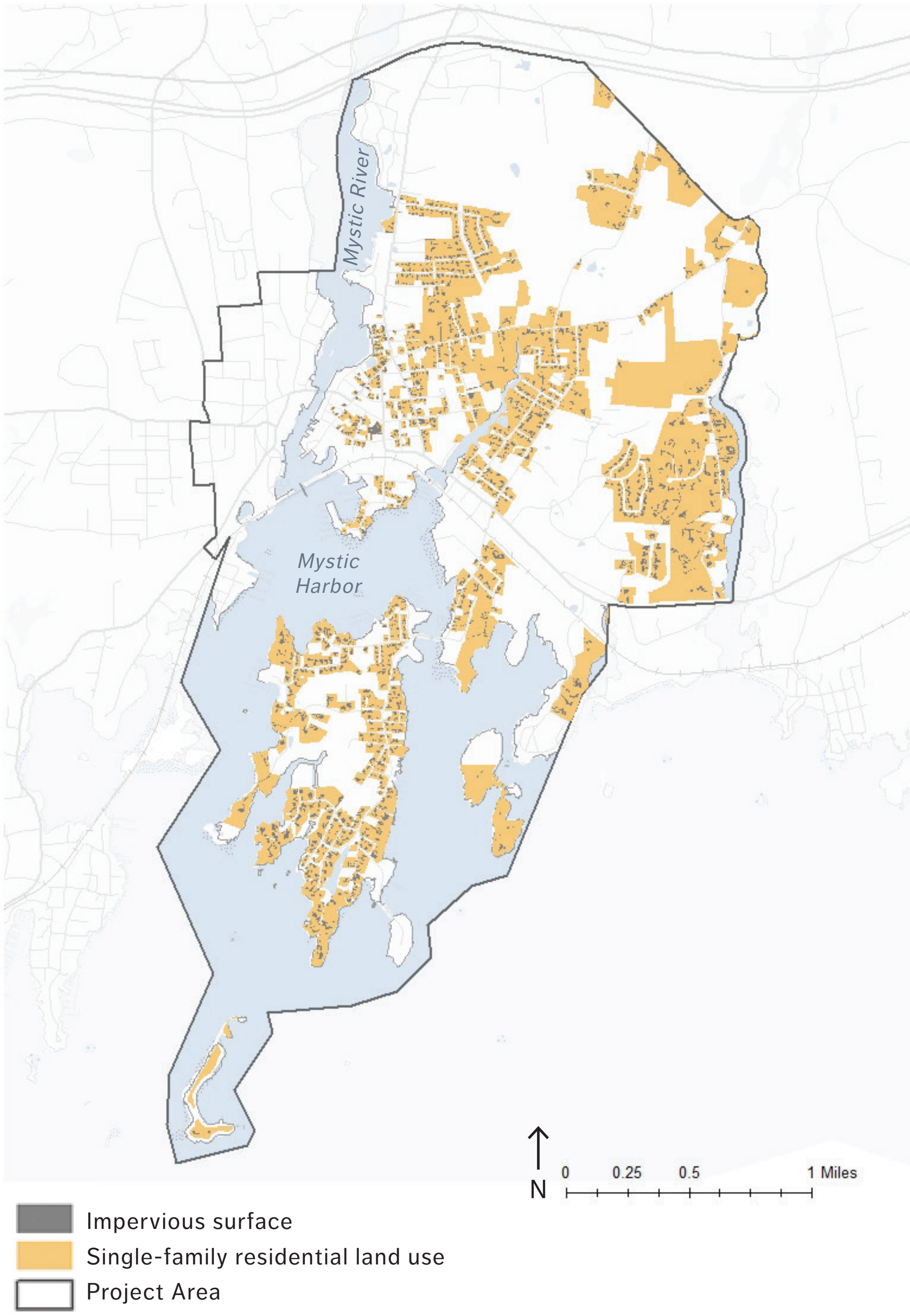
Using the above equation and a runoff coefficient of .9, we find that on the average residential property, 1" of rain yields approximately 1,346 gallons of runoff.

Residential stormwater interventions allow this water to filter into the ground, effectively treating it onsite and keeping it out of the storm system, if infiltration allows. If implemented on a neighborhood scale, these interventions can have a major impact on improving water quality and reducing the volume of runoff entering the municipal system.

Residential runoff can contain harmful and toxic pollutants, including nitrogen and phosphorus from fertilizers, bacteria and viruses from pet waste, herbicides, pesticides, sediment, and organic materials. Furthermore, runoff from driveways can contain heavy metals and other toxic chemicals from oil and grease (Office of Watersheds, 3). Green infrastructure can treat stormwater on residential properties, helping to improve water quality downstream by reducing pollutant loads while simultaneously providing other community benefits such as greening the town, enhancing wildlife habitat, and reducing the heat-island effect.

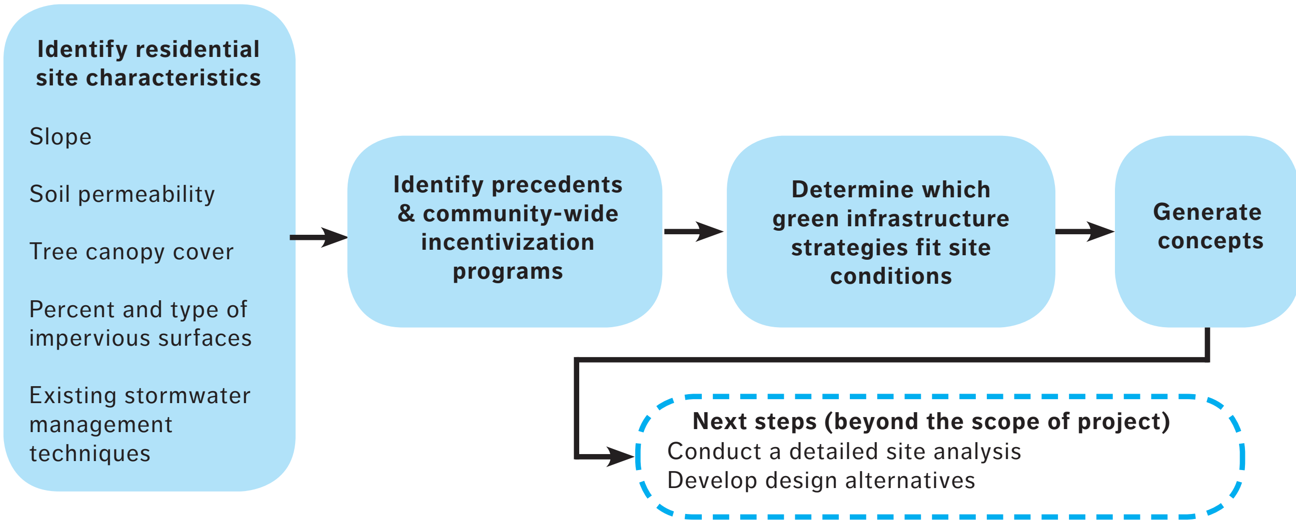
Encouraging residents to implement green infrastructure on-site reduces stormwater pollution and flooding, and can facilitate a community-wide discussion about watershed health and climate resilience. The 2017 *Coastal Resilience Plan* pointed to residential, small-scale interventions as an important means for climate adaptation and cited feedback from members of the community who expressed a strong interest in implementing strategies on their properties that reduce flooding and protect water quality (Town of Stonington et al., 131). Furthermore, small-scale residential interventions can help the town meet MS4 minimum control measure #1: public education and outreach. To meet this measure, the Stonington Stormwater Management Plan has already set forth the goal to "motivate residents to use Best Management Practices (BMPs) which reduce polluted stormwater runoff" (Fuss & O'Neill, 12).

Single-Family Residential Land Use and Impervious Surfaces



DESIGN PROCESS

A four-step design process was developed to illustrate green infrastructure strategies for residential property owners and to draft municipal recommendations for the project area. Residential characteristics were mapped using GIS data from CT DEEP and CT ECO. Green infrastructure strategies were chosen based on spatial constraints and their ability to filter stormwater, green neighborhoods, and inspire community dedication for watershed health.



RESIDENTIAL CHARACTERISTICS

Slope, soil, tree canopy cover, impervious surfaces, and existing stormwater management techniques were analyzed in ArcMAP to determine the average site conditions of single-family homes within the project area. Based on these conditions and the spatial criteria for each type of green infrastructure strategy (see Toolbox), the most applicable strategies for average site conditions were determined.

Within the project area, most single-family residential properties are relatively flat (<5% slope). According to the NRCS soil survey, soils are generally well-draining. However, due to the highly urbanized nature of the project area, some properties may contain compacted soil. The average residential parcel within the project area is covered by 12% impervious surfaces with an average of 38% tree canopy cover. Some residences have gutters that tie directly into the municipal stormwater system.

The illustrations shown on the following pages reflect a typical, single-family home, and the complementary green infrastructure strategies that can help to reduce and treat stormwater runoff. Although not all strategies are appropriate for every residential property, users can assess their applicability and adapt designs by noting spatial criteria and site conditions outlined in the Toolbox section of this book. These interventions can also be applied in similar contexts on non-residential sites and public sites. The *Coastal Resilience Plan* suggests the importance of implementing strategies that reduce the risk of flooding on historic structures, as they may be more expensive to repair in the event of flooding, and damage or loss could impact tourism and the aesthetic qualities of historic neighborhoods (Fuss & O'Neill, 18).

While green infrastructure strategies reduce the volume of runoff and improve water quality, a high water table may prevent infiltration and therefore may limit their ability to reduce flooding from back flowing storm drains or during high precipitation events.

The following strategies are broken into two categories: Residential Strategies to Reduce and Filter Stormwater and Municipal Recommendations. For residential recommendations to manage coastal flooding, refer to *Shoreline Interventions for Coastal Resilience.*

Rain barrels capture roof runoff that can be used in gardens on residential properties.

Residential Strategies to Reduce Stormwater Runoff and Improve Water Quality

PLANT TREES

Trees intercept and store rainwater in their canopy and lift water out of the ground through their roots, thus significantly reducing the amount of stormwater runoff on a given property. They also shade surfaces underneath, cooling runoff moving across these surfaces.
(p.43)

PLANT RAIN GARDENS (SMALL BIORETENTION AREAS) & REDUCE GRASS TURF

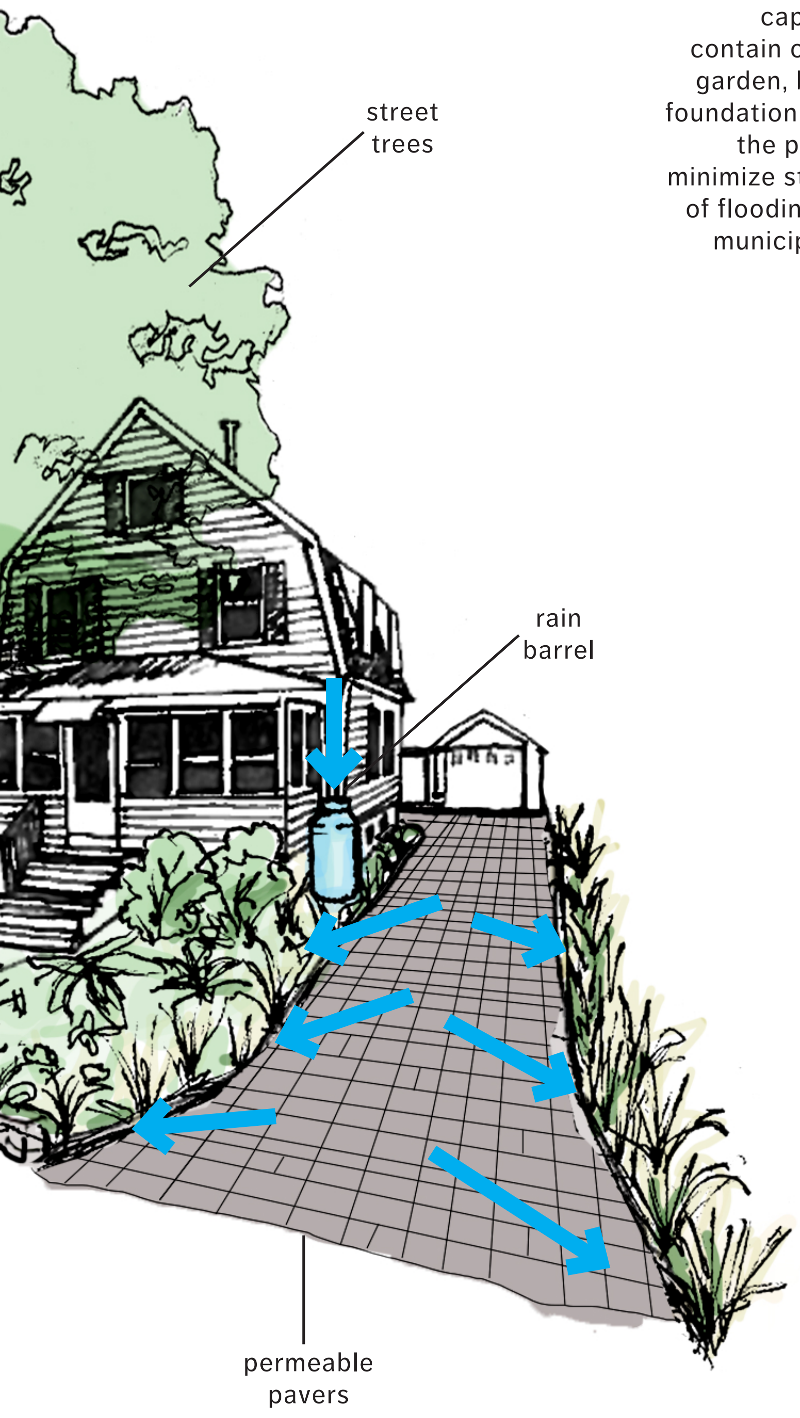
Replacing grass turf with plants that have a high capacity to absorb water and do not produce and impervious layer of thatch can decrease the amount of stormwater leaving a site. Strategies include planting more shrubs, rain gardens, and bioswales. *(Toolbox p. 49)*

AVOID CHEMICAL USE ON LAWNS

Avoiding the use of herbicides and pesticides helps to improve the water quality of residential runoff. Conducting a soil test will help determine any nutrient deficiencies for which organic fertilizers can help amend. Alternatively, choose plants that are tolerant of existing soil conditions. Additionally, picking up and properly disposing pet-waste can prevent harmful bacteria from entering nearby waterways.

INSTALL CURB-CUTS AND REGRADE DRIVEWAYS AND ROADS

Manipulating existing impervious surfaces can help direct runoff into permeable areas. Techniques include curb-cuts and regrading driveways and streets to convey runoff from these surfaces into rain gardens.



DISCONNECT GUTTERS AND CAPTURE/ STORE RAINWATER

Install or connect existing gutters to rain barrels or cisterns to capture rainwater from roofs. Storage containers should also contain overflow mechanisms that release excess water into a rain garden, bioswale, or french drain that directs water away from the foundation of the house. Delaying the release of stormwater reduces the peak runoff rate from a property at a given time, helping to minimize stress on the municipal system and decrease the likelihood of flooding. Residences that have gutters directly connected to the municipal stormwater system should consider disconnection and implementation of these techniques. *(Toolbox p. 56)*

MAINTAIN VEHICLES

Performing regular maintenance on vehicles can reduce the likelihood of oil leaks. Additionally, because commercial car-washing facilities must obtain a permit for wastewater discharge and adhere to specific standards that protect the environment, washing cars in designated facilities instead of in residential driveways reduces the likelihood of phosphates from soap, hazardous chemicals, and heavy metals entering nearby waterways. Other strategies include recycling used motor-oil, using ground cloths or drip pans under vehicles in the event of a leak or during engine maintenance, and cleaning up immediately after a spill.

INSTALL PERMEABLE DRIVEWAYS

Pervious pavement or permeable pavers can be used as a replacement for the traditional asphalt driveway. These strategies have the potential to reduce the amount of runoff leaving a property by allowing stormwater to filter into an underground stone reservoir and eventually into the ground. Because runoff from driveways can contain harmful chemicals from vehicles, reducing the amount that enters the municipal system improves water quality of nearby water bodies. *(Toolbox p. 54)*

Municipal Recommendations

By supporting and incentivizing stormwater interventions on residential properties, local and state governments have the opportunity to reduce and treat stormwater, meet MS4 regulations, and inspire a community dedicated to watershed health and climate resilience. While most green infrastructure strategies require initial spending, treating stormwater before it enters the municipal system reduces the cost that a town would otherwise spend managing the system and resizing it to accommodate more runoff. It also presents an opportunity for community engagement and greening neighborhoods. Strategies include:

IMPLEMENT TREE PLANTING PROGRAMS

Offer to plant shade trees on private properties at no cost and educate community members about tree care and maintenance.

IMPLEMENT STORMWATER UTILITY

Stormwater utilities can incentivize retrofits of existing properties and implementation of green infrastructure on new developments (U.S. EPA 2009a). The utility reflects the amount the municipality would need to spend to manage the stormwater from the property. Owners can reduce their utility or receive credits by reducing impervious cover, disconnecting gutters from the municipal stormwater system, and implementing green infrastructure strategies (WERF). Money collected from this utility can go towards helping municipalities implement and maintain green infrastructure projects.

CREATE DEVELOPMENT INCENTIVES

Remove or decrease fees, requirements, or steps in the permitting process for new developments that implement green infrastructure strategies.

OFFER REBATES AND GRANTS

Provide rebates for materials that help with stormwater reduction such as rain barrels and drought and water-tolerant plants, and offer grants to property owners for reducing impervious area and/or implement other green infrastructure strategies (WERF).

GIVE AWARDS AND RECOGNITION

Offer awards or recognition to property owners that implement BMPs that reduce impervious area and/or implement green infrastructure strategies (WERF).

ENGAGE THE COMMUNITY

Educating community members about stormwater and watershed health can build support for municipal green infrastructure projects and can inspire residents to implement green infrastructure on their own properties.

Photo Credit: Steve Chou

Reducing Urban Runoff by Greening Philadelphia

Case Study: Philadelphia, PA
(Philadelphia Water Department)

In an effort to reduce urban runoff and improve the quality of runoff entering nearby water bodies, the Philadelphia Water Department (PWD) has implemented a number of stormwater reduction strategies. For example, its residential stormwater billing program charges users a monthly fee as part of their water bill based on the amount of impervious surface on their property and the cost of treating stormwater. To help residents reduce stormwater fees and implement stormwater reduction strategies, the City provides online tools and offers incentives. For example, an online Stormwater Parcel Viewer allows users to measure parcel area and impervious surfaces to see which stormwater interventions are appropriate and where. Additionally, the PWD offers free rain barrels and subsidizes residential landscape improvements that manage stormwater. They also host public workshops, teach about stormwater in public schools, and publish resources such as the Homeowner's Stormwater Handbook in an effort to create a community committed to watershed health.

Green Streets

GREEN INFRASTRUCTURE STRATEGIES FOR STORMWATER MANAGEMENT ON MUNICIPAL AND STATE-OWNED RIGHTS-OF-WAY, INCLUDING PARKING LANES, SIDEWALKS, AND MEDIANS.

WHY GREEN STREETS?

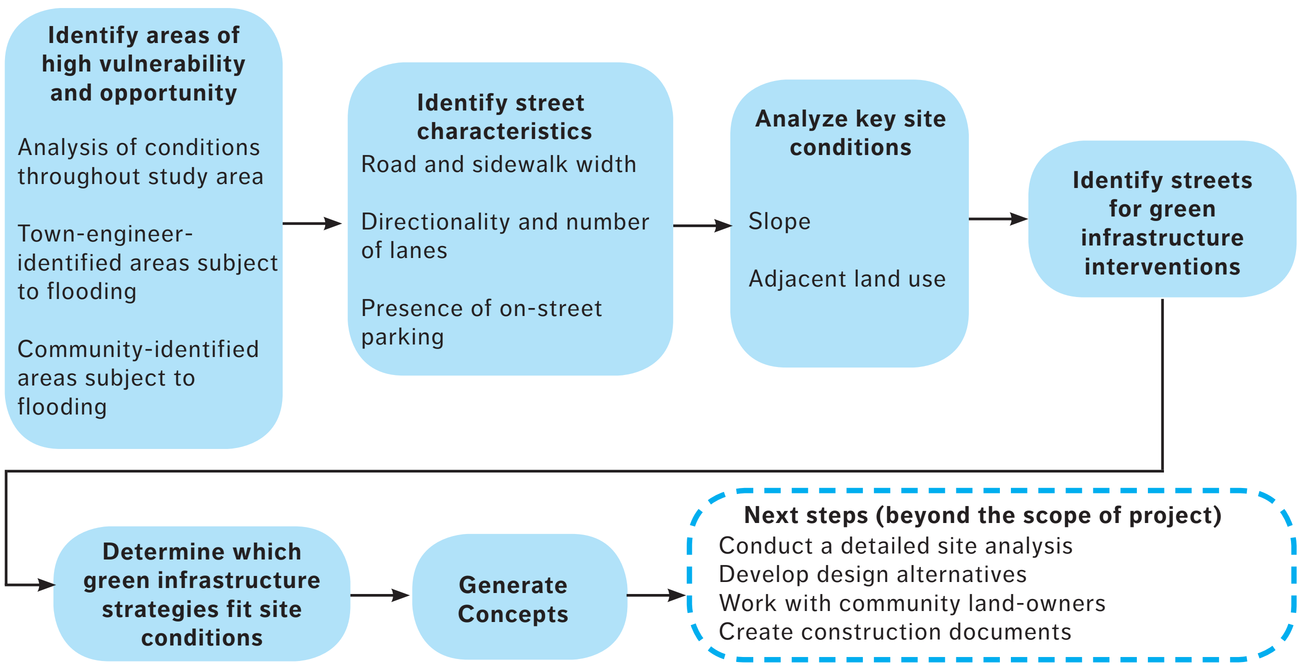
Green Streets are an approach to managing stormwater by using green infrastructure to treat runoff at the source. By replacing impervious surfaces with vegetation, soil and other permeable materials, stormwater runoff is slowed, filtered, and reduced. This can decrease the likelihood of flooding and improve the quality of downstream water bodies (U.S. EPA 2015). Green Streets can also create more beautiful urban streetscapes, reduce the heat island effect, and improve air quality. Using the Green Streets approach, Mystic has an opportunity to create a resilient urban environment, garner support for watershed health, and inspire similar coastal communities.

The 2017 *Coastal Resilience Plan* (CRP) noted that as sea levels rise and precipitation rates increase due to climate change, accessing important facilities such as hospitals, police stations, and emergency centers in Mystic may become challenging due to flooding along major roadways (Town of Stonington et al. 22). The CRP lists Route 27 and Route 1 as particularly vulnerable because of their tendency to flood and their value as commuter corridors (Town of Stonington et al. 16). Other streets identified by community members and Scot Deledda, the town engineer, as places that frequently flood include Church Street, Cottrell Street, and Washington Street. Flooding on streets can damage infrastructure and vehicles, and can lead to road closures—consequently impacting daily life and reducing tourist activity.

DESIGN PROCESS

Street characteristics and site conditions inform the suitability and location of green infrastructure strategies. For example, strategies differ depending on the width of the right-of-way (ROW), lane directionality, presence of designated on-street parking, speed limit, slope, proximity to pollution hot-spots, and land use. For detailed information on spatial criteria and optimal site conditions for each green infrastructure technique, please refer to the Toolbox section of this book.

A six-step design process was developed to identify and illustrate Street Profiles that exemplify the range of street characteristics in Mystic and the diversity of green infrastructure techniques that can be applied. Streets were analyzed using GIS data from CT DEEP, CT ECO, the Town of Stonington's Geographic and Property Information Network, and Google Earth. Additionally, areas that experience frequent flooding were identified by community members and the Town Engineer, Scot Deledda. The existing municipal stormwater infrastructure was considered in the following conceptual designs; however, the location of other underground utilities was not. Therefore, further analysis is needed as underground utilities will likely impact the location and design of proposed strategies.



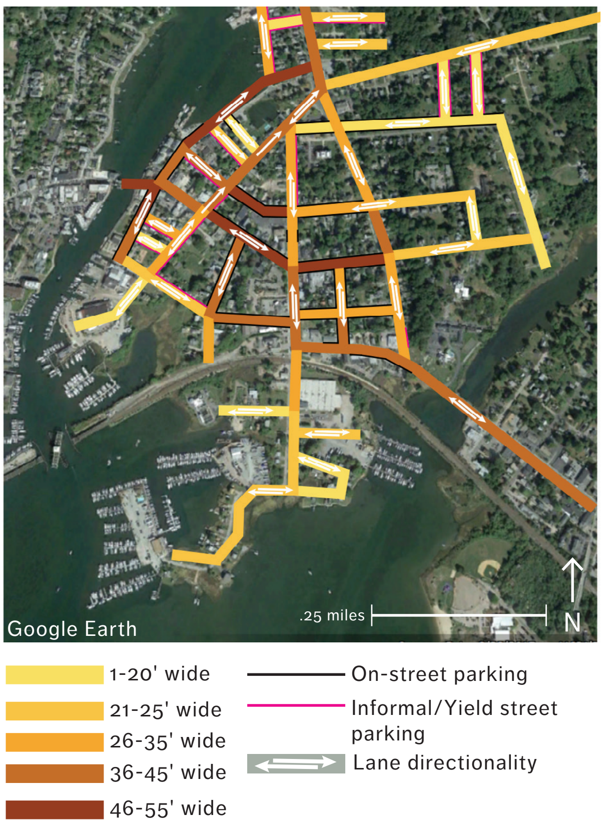
STREET CHARACTERISTICS

The majority of streets in the village of Mystic are between 25' and 45' wide, with two-way directionality of travel, and speed limits between 25 and 35 mph. Most streets have on-street parking that is either delineated with striping or by the absence of "no parking" signs. With the exception of Mistuxet Avenue, School Street, East Church Street, and Reynolds Street, streets are generally flat with slopes <5%. Land use within the village of Mystic is primarily commercial and residential.

Based on these characteristics and conditions, and areas identified through the process of analysis and community feedback as highly vulnerable, five Street Profiles were created to show conceptual applications of green infrastructure techniques to a range of conditions in Mystic. Each Street Profile represents a distinct street in Mystic, but can be applied elsewhere where similar conditions exist.

Green infrastructure techniques applied to street profiles manage stormwater, increase canopy cover, and improve the aesthetic quality of a neighborhood. Preserving existing on-street parking was a major priority as city officials and community members noted concern about a lack of parking during peak tourist season.

Street Characteristics in the Village of Mystic



Local Flooding Impacts on Visitation to Downtown Districts

Case Study: Annapolis, MD (Masters)

A study in Annapolis, MD, analyzed data from parking meters and comments on Twitter from local businesses to understand the economic impacts of flooding. They reviewed 4,584 hours of parking meter records and found that when flooding occurred as a result of high tides and sea level rise, people avoided the downtown area altogether. Even after the flooding ended, there was more than a six-hour lag until visitation returned to its usual levels. This resulted in a 2% loss of visits (3,000 lost visits) to the historic downtown district, at a cost of $86,000 - $176,000 per year.

Street Characteristics

1 COTTRELL STREET

Cottrell Street runs parallel to the Mystic River and abuts Mystic Harbor, making it particularly vulnerable to flooding from precipitation, storm surge, and sea level rise. Stormwater from nearby impervious surfaces is funneled into several catchment basins that line both sides of the street. Cottrell Street is in the heart of Mystic's commercial district and experiences heavy pedestrian and vehicle use. On-street parking is valuable and lines both sides of the street. The area is highly developed with structures encroaching on the right of way, and there is a large amount of impervious surface and minimal tree canopy cover.

2 CHURCH STREET

During heavy precipitation events, runoff from steep slopes to the east can collect on this section of Church Street and result in flooding. Additionally, high water levels in the Mystic River can cause water to back-flow through outfalls and up through catchment basins, which prevents stormwater from draining. The area is primarily residential, and the street abuts St. Patrick's Church, an important community asset. St. Patrick's Church has a large parking lot that drains to catchment basins along the north and south edges of Church Street.

3 EAST MAIN STREET

East Main Street is part of Route 1, a street identified in the 2017 *Coastal Resilience Plan* (CRP) as a location where green infrastructure may help to mitigate the impacts of flooding. Curbs funnel runoff into catchment basins, of which there are fewer compared to streets to the south and west. It is a main arterial road that connects the towns of Stonington and Groton, and runs through downtown Mystic Village. It is also frequented by pedestrians, with sidewalks lining both sides of the street. The CRP identified this area as high risk to flooding because of its location along the coastline and a priority for intervention because of its use as a major commuter corridor.

4 BROADWAY STREET

The southern section of Broadway Street is also part of Route 1. There are several gas stations within this section of Broadway Street and there is a high concentration of impervious surfaces. Thus, it is possible that runoff from this area may contain higher amounts of potentially harmful pollutants. There is minimal tree canopy cover. Curbs direct stormwater into catchment basins that line both sides of the street.

5 REYNOLDS STREET

Reynolds Street is one of the few streets in Mystic with a >10% slope. During heavy rain events, the road acts as a channel, transporting runoff from the higher elevations to low-lying areas. It is primarily lined with residential buildings and has minimal pedestrian and vehicle traffic. The right-of-way extends an additional 8-12 feet on either side beyond the paved road and is currently mowed grass. There is more tree canopy cover on Reynolds Street compared to the streets closer to the coastline.


2
3
1
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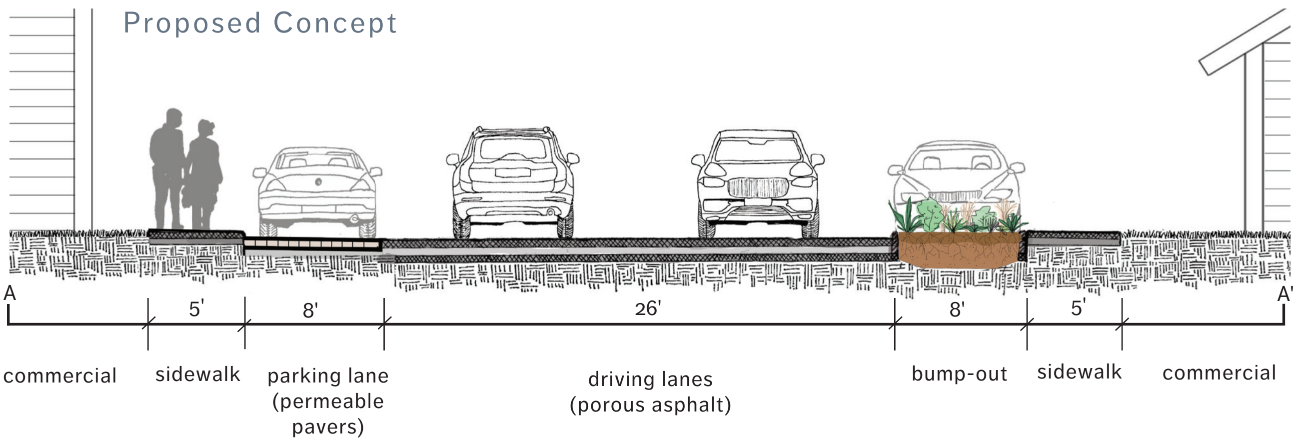
4
Google Earth

① Street Profile: Cottrell Street

Flood Risk	ROW Width	Speed Limit	On-Street Parking	Sidewalks	Adjacent Land Use	Slope
High	52'	25 mph	Yes (both sides)	Yes (both sides)	Commercial	<5%



GREEN INFRASTRUCTURE TOOLS

- Bump-out *(Toolbox p. 52)*
- Rain garden *(Toolbox p. 52)*
- Permeable pavers *(Toolbox p. 54)*
- Porous asphalt *(Toolbox p. 54)*

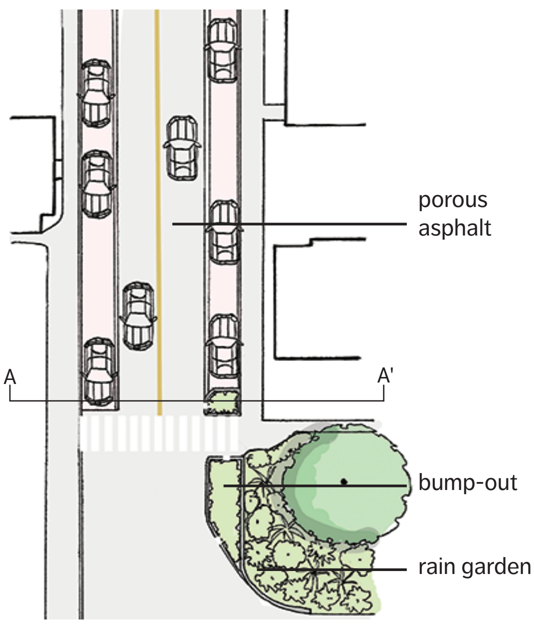
ADVANTAGES AND LIMITATIONS

Filtering runoff from Cottrell Street, an area with high concentrations of impervious surfaces, can help maintain healthy water quality of nearby water bodies. This can be a challenge due to limited space; however, permeable pavers in parking lanes allow water to filter into the ground and preserves parking. Additionally, curb extensions at crosswalks slow and filter water, as well as shorten the time pedestrians are exposed to oncoming traffic while crossing the street. Finally, underutilized green space, such as that owned by the Town of Stonington at the southern end of Cottrell Street, can be used for small-scale stormwater detention in a rain garden.

Although these strategies can store some runoff on the surface and just below, larger volumes of underground storage may not be feasible due to soil percolation rates. While these strategies can improve water quality they may not significantly reduce flooding from back-flowing storm drains or during high precipitation events.

ADDITIONAL CONSIDERATIONS

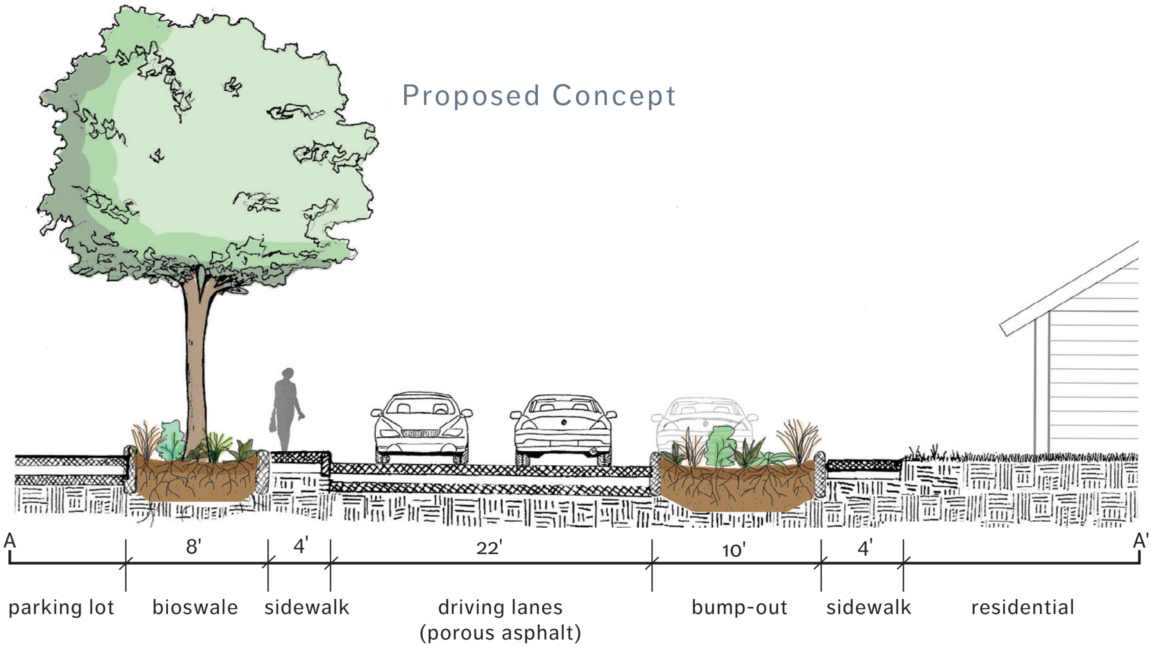
In areas with high pedestrian activity like Cottrell Street, green infrastructure can help educate and inspire community members and tourists about stormwater management and ecosystem and watershed health. The Town of Stonington is considering making Cottrell Street one-way, which would create space for additional green infrastructure strategies.



Plan view of Cottrell Street with Green Infrastructure Interventions.

② Street Profile: Church Street

Flood Risk	ROW Width	Speed Limit	On-Street Parking	Sidewalks	Adjacent Land Use	Slope
High	50'	25 mph	Yes (one side)	Yes (both sides)	Commercial	<5%



GREEN INFRASTRUCTURE TOOLS

- Bioswale *(Toolbox p. 49)*
- Bump-out *(Toolbox p. 52)*
- Porous asphalt *(Toolbox p. 54)*
- Street trees *(p. 43)*

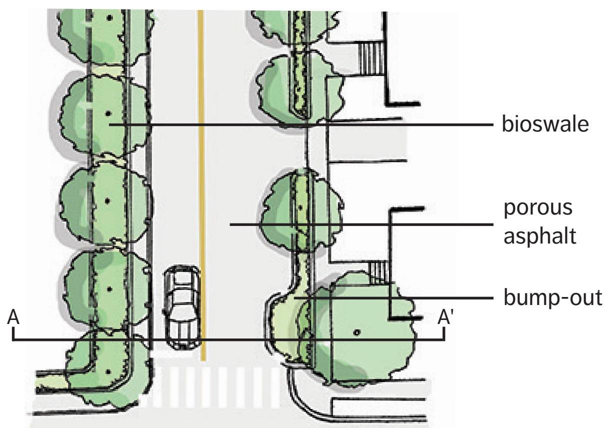
ADVANTAGES AND LIMITATIONS

Green infrastructure strategies that intercept runoff from the St. Patrick's Church parking lot and along the north side of Church Street have the potential to slow stormwater before it enters the municipal system and reduce the occurrence of nuisance flooding. Because so many vehicles use the parking lot, stormwater in this area may contain higher pollutant loads. Filtering stormwater from the parking lot can reduce pollution in water bodies into which runoff is channeled.

However, due to a high water table, these strategies may not significantly reduce flooding from back-flowing storm drains or during high precipitation events. While bump-outs slightly reduce parking availability, expanded parking is proposed in an adjacent lot. *(See page 68)*

ADDITIONAL CONSIDERATIONS

Partnering with and incentivizing community groups like St. Patrick's Church to reduce impervious surfaces and manage stormwater on-site can help the Town of Stonington build partnerships centered around watershed health and community resilience. Also, installing back-flow preventers at the nearby outfall may reduce flooding during high tides or storm surge.

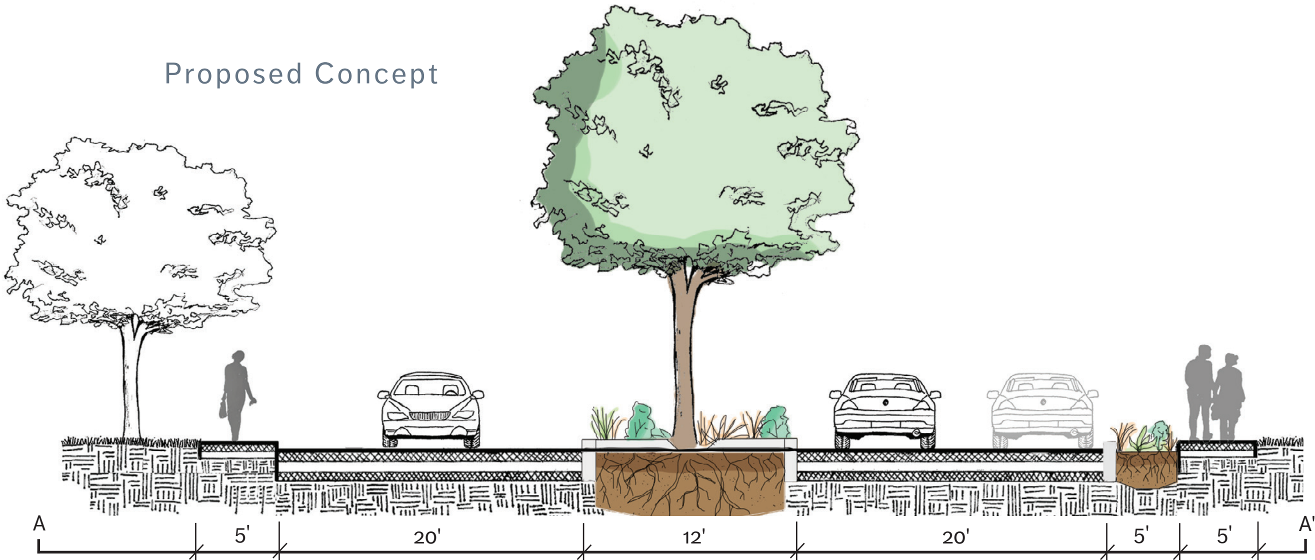


Plan view of Church Street with Green Infrastructure Interventions. N→

③ Street Profile: East Main Street (Route 1)

Flood Risk	ROW Width	Speed Limit	On-Street Parking	Sidewalks	Adjacent Land Use	Slope
High	67'	25 mph	Yes (one side)	Yes (both sides)	Commercial	<5%

Proposed Concept



GREEN INFRASTRUCTURE TOOLS

- Bioswale in median *(Toolbox p. 49)*
- Bioswale *(Toolbox p. 49)*
- Street trees *(p. 43)*
- Porous asphalt *(Toolbox p. 54)*

ADVANTAGES AND LIMITATIONS

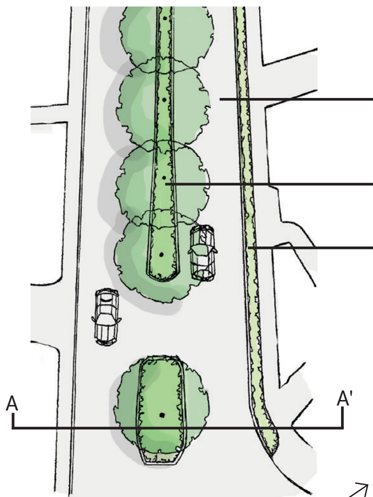
Trees and other plants tolerant of periods of drought and inundation that are planted in the existing median will intercept rain and reduce the amount of runoff entering the municipal system. Additionally, street trees provide shade for parked cars and pedestrians and improve the aesthetics of the road.

In order for stormwater to enter the bioswales, curbs must be cut so that they are level with existing road.

While they offer some storage, due to a high water table, these strategies may not significantly reduce flooding from back-flowing storm drains or during high precipitation events.

ADDITIONAL CONSIDERATIONS

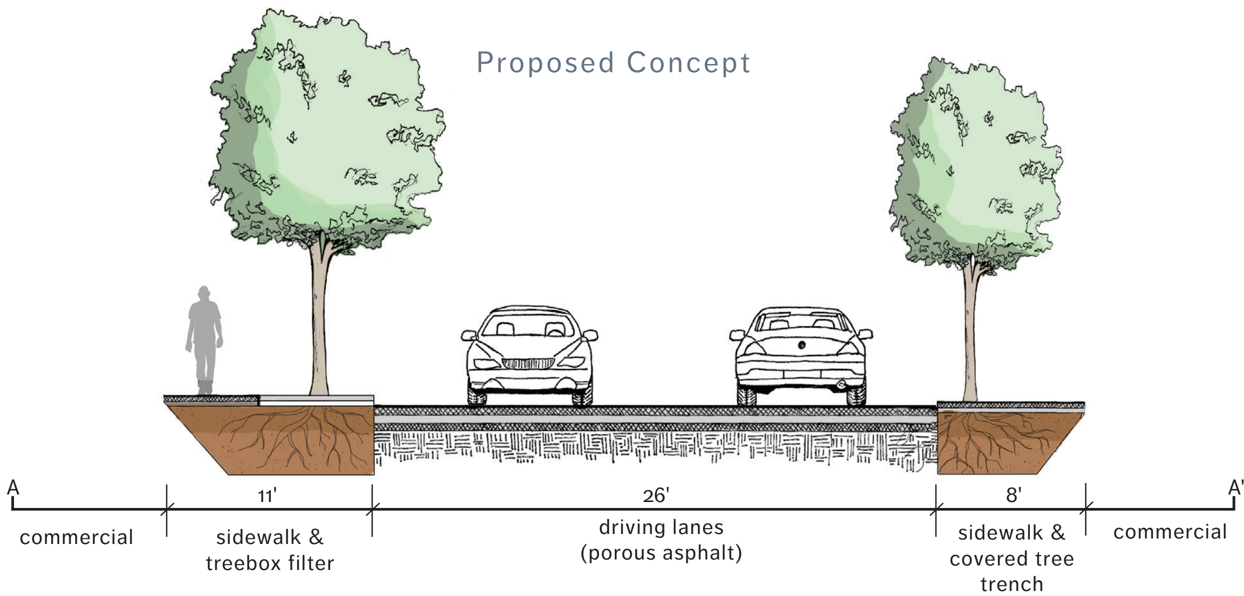
Route 1 is managed by the CT Department of Transportation. Standards for green infrastructure and maintenance may differ on the state level. Further investigation of design standards is needed.



Plan view of E Main Street with Green Infrastructure Interventions.

④ Street Profile: Broadway Street (Route 1)

Flood Risk	ROW Width	Speed Limit	On-Street Parking	Sidewalks	Adjacent Land Use	Slope
Medium	45	25 mph	No	Yes (both sides)	Commercial	<5%



GREEN INFRASTRUCTURE TOOLS

- Treebox filter *(Toolbox p. 51)*
- Covered tree trench *(Toolbox p. 50)*
- Porous asphalt *(Toolbox p. 54)*

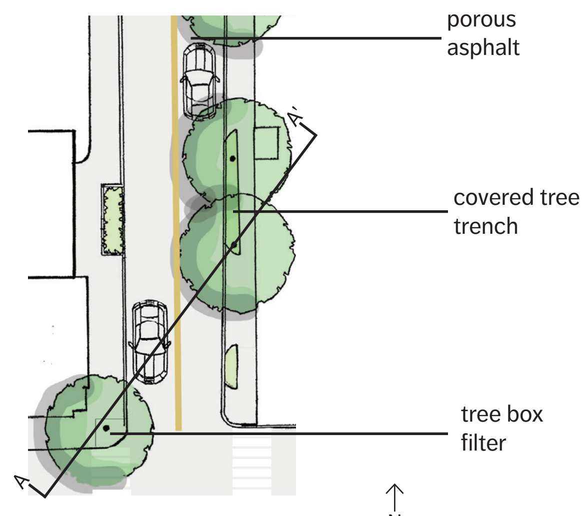
ADVANTAGES AND LIMITATIONS

This section of Broadway Street (Route 1) has a high concentration of impervious surfaces as well as several nearby gas stations identified as pollution hot spots. Treebox filters and covered tree trenches filter water before it enters the municipal system. Additionally, they help to increase tree canopy cover in an area that is currently sparse. They also provide shade for parked cars and pedestrians and improve the aesthetics of the road.

These boxes will provide a degree of storage, though due to a high water table, they will not significantly reduce flooding from back-flowing storm drains or during high precipitation events.

ADDITIONAL CONSIDERATIONS

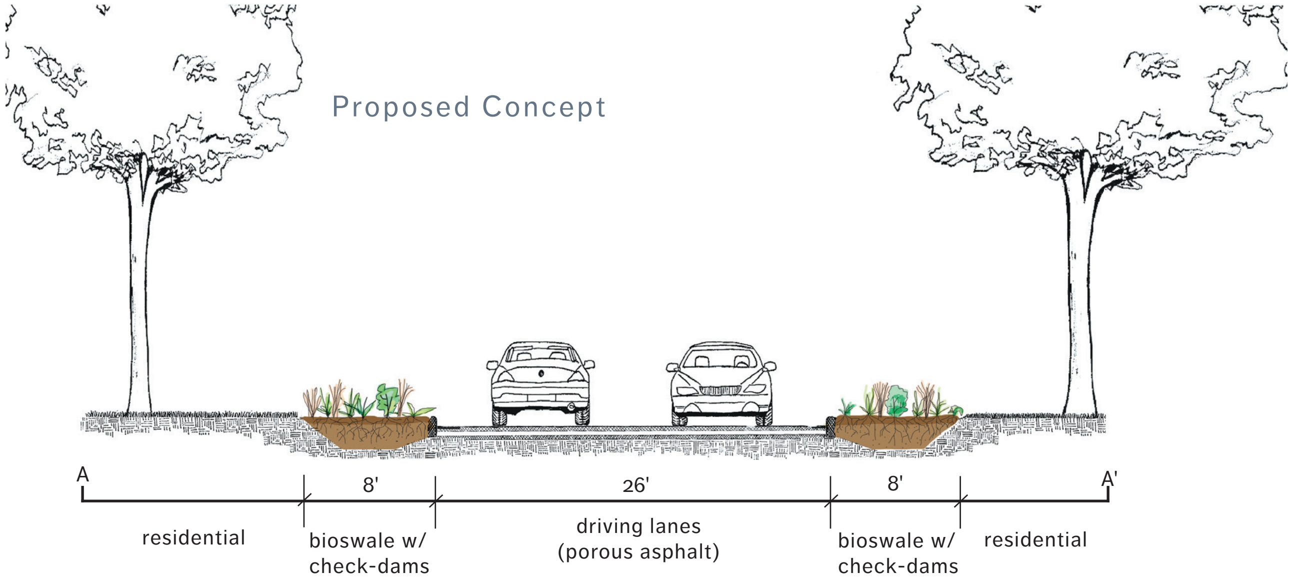
Route 1 is managed by the CT Department of Transportation. Standards for green infrastructure and maintenance may differ on the state level, so further investigation of design standards is needed before implementation.



Plan view of Broadway Street with Green Infrastructure Interventions.

⑤ Street Profile: Reynolds Street

Flood Risk	ROW Width	Speed Limit	On-Street Parking	Sidewalks	Adjacent Land Use	Slope
Low	42'	25 mph	No	No	Residential	>10%



GREEN INFRASTRUCTURE TOOLS

- Bioswale with check-dams *(Toolbox p. 49)*
- Porous asphalt *(Toolbox p. 54)*

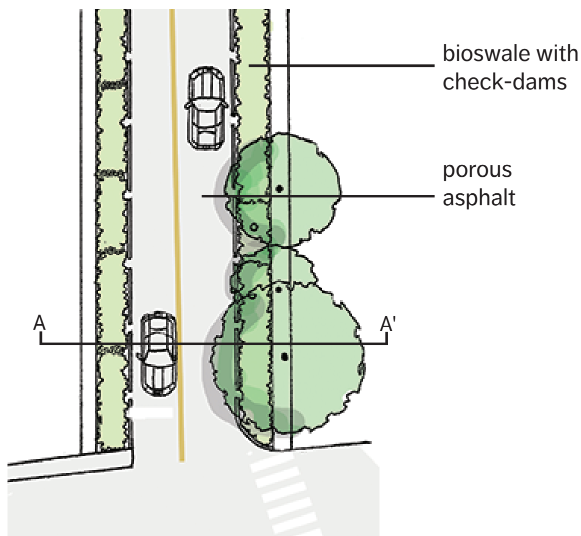
ADVANTAGES AND LIMITATIONS

Intercepting runoff from streets with steeper slopes and at higher elevations has the potential to significantly reduce flooding in lower-lying areas. The water table may be lower further up hill on Reynolds Street than it is underneath streets at lower elevations. Larger volumes of water may infiltrate into the ground. By regrading and using curb-cuts to direct water into bioswales, stormwater is directed away from impervious surfaces and into vegetated channels. This strategy also filters water through vegetation and soil, subsequently improving water quality.

Bioswales along the southern side of the street are especially important because they can overflow or connect directly to the storm drain at the bottom of the hill. However, they will need to be spaced accordingly so that they do not interfere with existing telephone poles.

ADDITIONAL CONSIDERATIONS

Green infrastructure along residential streets can reduce the impacts of stormwater on private properties and inspire residents to implement additional strategies within their yards. Furthermore, it can help improve property value and add to the aesthetics of a neighborhood.



Plan view of Reynolds Street with Green Infrastructure Interventions.


Street trees line an urban street. Photo credit Kris Arnold

Next Steps

SIZING GREEN INFRASTRUCTURE

Many of the impacts of climate change are unpredictable. A combination of responses, including appropriately sized green infrastructure systems may help the Mystic community adapt to increased stormwater and mitigate its effects. For more long-term solutions, larger scale engineering solutions may be required including upgrading the existing municipal gray infrastructure system.

While much of the long-term potential of green infrastructure is still unknown, research documents the benefits of green infrastructure systems when tested within a simulated climate model. Engineers, consultants and researchers from Tetra Tech and the U.S. EPA tested the adaptability of commonly used green infrastructure techniques to accommodate increasingly frequent and heavy storms due to a changing climate. They evaluated infiltration swales, bioretention areas, and green roofs in a range of urban areas across the United States, and concluded that green infrastructure can substantially reduce surface runoff, control pollutant loads, and increase evapotranspiration (Sarkara, 32). They note that the current sizing requirements of green infrastructure in many urban Best Management Practices manuals may not account for increased precipitation; adaptation and expansion over time may be required to meet the needs of a changing climate. The costs of making adjustments over time to green infrastructure are far less than adapting existing gray infrastructure, and the costs of extensive projects can be reduced if the initial design strategies consider that "planning ahead requires paying attention to the highest risk scenarios" (Town of Stonington et al., 7). Calculating runoff volumes for different storm scenarios within a given watershed catchment area will help determine the appropriate size of green infrastructure strategies.

Appropriate sizes of large interventions combined with the cumulative effect of many small-scale interventions have the potential to intercept large volumes of stormwater runoff. In a separate study, Thiagarajan M. et al. used a stormwater management calculator and found that if all the homes in the Sugar Land Community of Houston, Texas, implemented home-scale stormwater intervention strategies, a significant amount of flooding would be intercepted.

This is inspiring because small scale interventions are often far less costly and require less excavation than large scale interventions. They are also far easier to maintain and repair, although they are reliant on private homeowners for implementation and maintaintenence. Strategies to fund green infrastructure across the United States have included both incentive programs and stormwater utilities, and may be necessary when launching such a program, in conjunction with public education and outreach campaigns (Staddon, 332).

In urban settings, green and gray infrastructure are not mutually exclusive. The benefits of a hybrid approach to green and gray infrastructure include reduced pressure on gray infrastructure systems and fewer large-scale system repairs. Increased ecological benefits of green infrastructure include pretreatment for nutrient and sediment removal, and reduced runoff volumes by holding, absorbing or allowing water to evaporate, thereby preserving the aquatic habitats in the adjacent water bodies that are connected to the stormwater system outfalls. Green infrastructure also provides co-benefits such as carbon sequestration, habitat and urban greening, and the opportunity to develop a workforce skilled in design, installation, and sustainable maintenance of ecologically integrated stormwater management systems.

CITY-WIDE MAINTENANCE

The success of green infrastructure relies on accountability, proper maintenance, and financial and community support.

The U.S. EPA examined the Operations and Maintenance (O&M) regimes of 22 green infrastructure projects to determine the most relevant strategies that helped the projects succeed. These included:

- Creating an Operations and Maintenance manual that outlines specific maintenance procedures and clearly identifies responsible parties.
- Documenting and tracking green infrastructure projects to maintain a record of costs and ensure that each project is performing to the standards it was designed.
- Providing training and education on green infrastructure maintenance.
- Ensuring dedicated funding sources.
- Ensuring that green infrastructure projects withstand changes in leadership or shifts in government priorities.

(U.S. EPA, 2013b)

EDUCATION AND OUTREACH

To maintain momentum for green infrastructure projects, it is important to keep residents, commercial property owners, and other stakeholders engaged.

Small-scale residential strategies can significantly reduce runoff and improve water quality of nearby waterways. Thus, it is beneficial to build a coalition of people who value green infrastructure, understand how their own actions impact watershed health, and are encouraged to change behaviors that cause stormwater pollution. These individual changes are compounded when applied on a community-wide scale. Additionally, access to educational opportunities that guide residents on green infrastructure installation and maintenance ensures that green infrastructure projects operate according to the standards for which they were designed.

Another strategy for engaging with the community is partnering with local organizations. This helps to build relationships between local governments and community entities, diversify funding sources, and showcase green infrastructure in public-facing environments.

Additional strategies for community outreach and education include:

- Partnering with local schools to facilitate programs about stormwater, climate change, and watershed health.
- Offering tours of existing green infrastructure projects.
- Offering workshops on green infrastructure installation, maintenance, and care. (e.g. rain garden installation, rainwater harvesting, permeable paver installation, etc.)
- Creating green infrastructure demonstrations, e.g. work with multiple homeowners in several

neighborhoods to transform their properties into a demonstration of green infrastructure techniques. The Town could pay for installation and the homeowner would agree to maintain the intervention and allow tours.
- Creating brochures, manuals, and other educational materials for residential stormwater management.
- Hosting public events focused on stormwater, climate change, and watershed health.

For more information about community engagement visit the U.S. EPA's Engaging Stakeholders in your Watershed at: https://cfpub.epa.gov/npstbx/files/

FUNDING

Although green infrastructure strategies can be costly upfront, their ability to reduce flooding and improve water quality can save municipalities money over time. For example, one study by the Philadelphia Water Department measured the value of environmental, social, and public health benefits of several alternative ways of managing combined sewer overflows. They found that the total net benefits over 40 years ranged from $1.9 billion (managing 25 percent of impervious surfaces through green infrastructure) to $4.5 billion (managing 100 percent of impervious surfaces through green infrastructure) (Kramar, 9).

Funding for these projects can come from a variety of sources. Some municipalities use funds collected through a stormwater utility. Other sources include state, federal, and private grants such as:
- Long Island Sound Futures Fund
- CT DEEP Nonpoint Source Grant
- Connecticut's Clean Water Fund
- Connecticut Institute for Resilience and Climate Adaptation (CIRCA)
- Connecticut Recreational Trails Grants Program
- EPA Healthy Communities Grant Program
- Healthy Watersheds Consortium Grants
- Environmental Workforce Grant
- Community Development Block Grant
- The Clean Water State Revolving Fund
- FEMA Pre-disaster Mitigation Grant Program (PDM) and Hazard Mitigation Grant Program (HMGP)

MANAGED RELOCATION

Green infrastructure can reduce flooding and improve water quality in Mystic, but sea level rise and storm surges may require the community to consider relocating inland.

Communities in Northern Alaska are beginning to evaluate plans for managed relocation from coastal properties in order to let natural shoreline process take over, but in order to ensure successful implementation they must gain community support by carefully mitigating the associated psychological, symbolic, and sociological stressors (Ageyman, 510). After the 2011 Great East Japan Earthquake and Tsunami, a team of Harvard social scientists found that relocating communities in groups preserved social connections between individuals. It also promoted community resilience—mitigating the potential negative psychological impacts and isolation that can result from relocation (Hikichi, 2). When initially approaching the topic of managed relocation, discussions and educational events may help change cultural values and allow community members to develop adaptive strategies, such as having conversations about the importance of living shorelines. Community meetings may also lead to policy changes, including restrictions on building and zoning. This may have a stronger impact on shaping community behavior, including limiting development in sensitive areas and incentivizing owners of coastal properties to relocate. One of the influencers of human behavior and the desire to rebuild after a tragedy is the availability of disaster insurance, and once this is no longer an option people may be less eager to rebuild in vulnerable flood-prone areas (Keskitalo, 330).

Changing infrastructure to adapt to a changing climate, allowing coastal habitats to maintain their natural processes by enhancing habitats and allowing marshes to migrate, and redirecting development away from shorelines are ecological approaches that can reduce the need for relocation. Relocating away from coastlines may not be the most popular form of adaptation, but there may be a time when it is no longer a choice. But, for the immediate future, both small and large scale coastal and inland integration of nature-based green infrastructure solutions will work to reduce harmful impacts of flooding.

ASSESS ZONING PRACTICES

Zoning bylaws that encourage the use of green infrastructure and limit impervious surfaces can help residents, businesses, and developers reduce and treat stormwater.

The Town of Stonington should assess their current zoning practices and consider implementing the following:

- Encourage all new development to treat 100% of its stormwater on site.
- Encourage the use of green infrastructure for stormwater treatment.
- Incentivize tree planting on residential and commercial properties.
- Create an overlay district along the western face of the ridge that may have greater capacity for infiltration.
- Encourage all redevelopment to reduce impervious cover by 25% and/or treat all stormwater on site.
- Offer a reduction of parking requirements for new development and/or require that all new parking lots demonstrate the ability to treat 100% of stormwater from impervious cover.
- Consider sizing both municipal green and gray stormwater systems using a 50-year design storm.

CONTINUE THE CONVERSATION

A final community meeting was held March 12, 2019 at the Mystic Seaport Museum.
It was an opportunity for the Conway team to share the project process, gather feedback from the community, and identify the next steps for moving forward.

Community members recognized opportunities for potential local leadership coming from the local government (Boards of Selectmen and Departments of Planning, Engineering, and Transportation), conservation entities (Eastern Connecticut Conservation District, Connecticut Land Conservation Council, and the Wetlands Commission), and from within the community (Climate Change Task Force, private businesses, insurance companies, neighborhood online communities and listservs, garden clubs, scout groups, and rotary clubs).

Moving forward to enact resiliency plans includes partnering with groups currently working on climate resiliency issues. The community recognized the value in collaboration with The Nature Conservancy, Connecticut Institute for Resilience and Climate Adaptation (CIRCA), Stonington Climate Change Task Force, SeaGrant at University of Connecticut, CUSH (Clean Up Sound and Harbors), Mystic Aquarium, and Denison Pequotsepos Nature Center.

Community members would like to continue to be included in shaping the future of Mystic. Next steps that the community would like to see taken included the following:

- Host collaborative design charrettes with the community for the next phase of projects that are tailored to the needs and motivations of each neighborhood.
- Change regulations and zoning requirements to encourage green infrastructure.
- Create incentives for implementing residential designs (funding aid, tax incentives, and a stormwater utility tax).
- Educate community members about green infrastructure. Examples could include piloting public non-residential projects, creating residential green infrastructure certification programs, creating mass-mailings, and garnering media coverage.
- Continue partnership between Groton, Stonington, and other local communities.

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IMAGES

Mystic River: p.8-9
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Coastal Resilience Plan: p. 11
The Town of Stonington et al.

Green infrastructure: p. 13
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Trees: p. 42-43
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Stormwater basin: pp. 46-47
Chesapeake Bay Program
Rain Garden at U.S. Naval Academy

Mystic River Park: p. 73
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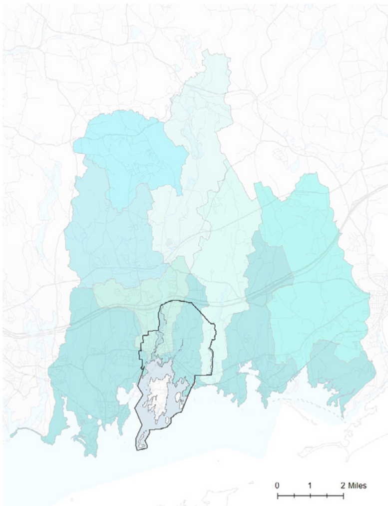
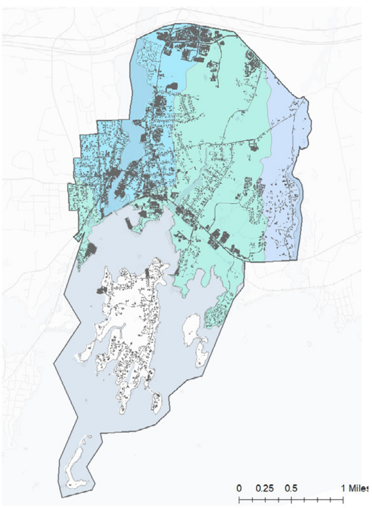
Data Sources for Maps



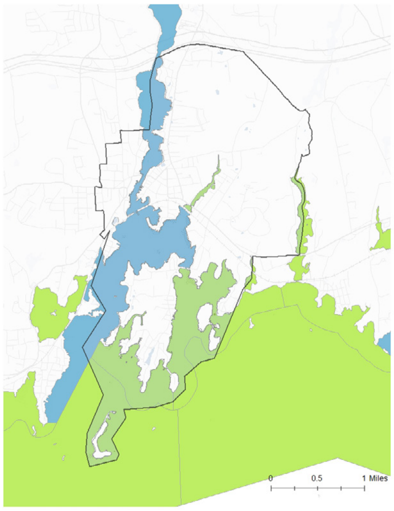
SUBBASINS OF THE SOUTHEAST COAST MAJOR WATERSHED (P. 21)

CT DEEP: Connecticut Environmental Conditions Online
- Connecticut Watershed Boundary



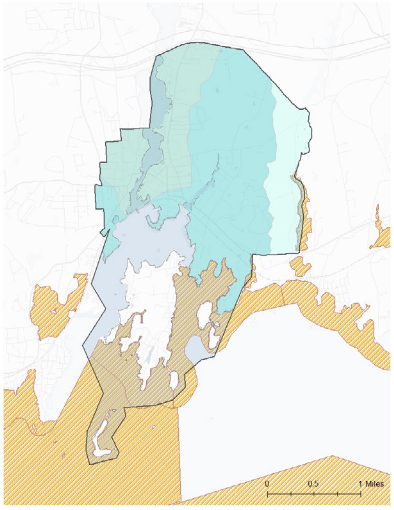
CONCENTRATION OF IMPERVIOUS SURFACE IN MYSTIC WATERSHEDS (P. 23)

CT DEEP: Connecticut Environmental Conditions Online
- Impervious Surface 2012
- Connecticut Watershed Boundary



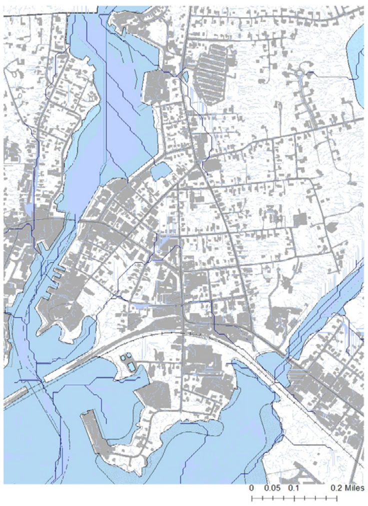
FEDERALLY ASSESSED ESTUARIES FOR SHELLFISH HARVESTING (P. 24)

CT DEEP: Connecticut Environmental Conditions Online
- Assessed Estuary 2016 CT 305B



IMPAIRED WATERS ALONG COASTAL AREAS OF MASON'S ISLAND AND STONINGTON (P. 25)

CT DEEP: Connecticut Environmental Conditions Online
- Connecticut Watershed Boundary
- Assessed River/Lake/Estuary 2014

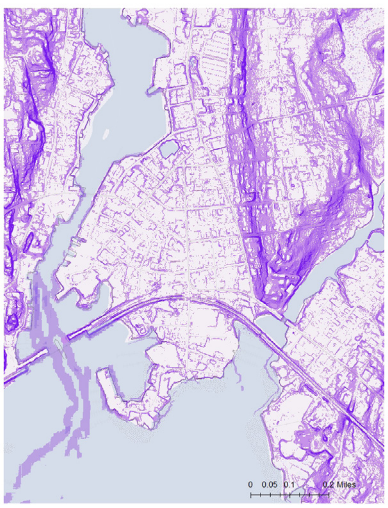


HEAVY FLOW ACCUMULATION IN DOWNTOWN MYSTIC (P. 26)

National Oceanic and Atmospheric Administration
- Light Detection and Ranging remote sensing data (LiDAR) Digital Elevation Model (DEM), 2016

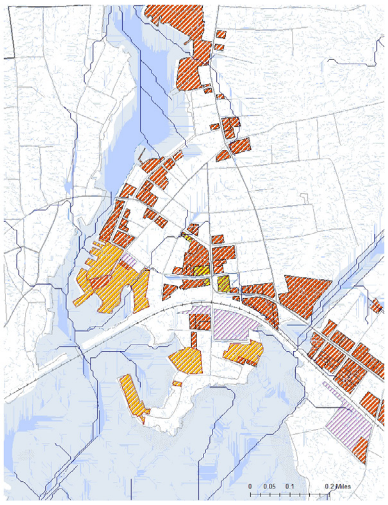
CT DEEP: Connecticut Environmental Conditions Online
- Impervious Surface 2012

Drainage Channels



DRAINAGE AND PERCENT SLOPE IN DOWNTOWN MYSTIC (P. 27)

National Oceanic and Atmospheric Administration
- Light Detection and Ranging remote sensing data (LiDAR) Digital Elevation Model (DEM), 2016



POLLUTION HOTSPOTS IN DOWNTOWN MYSTIC (P. 29)

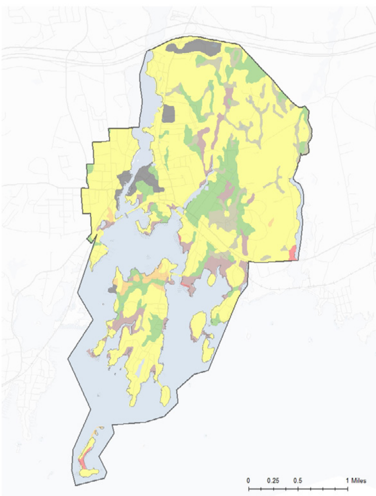
National Oceanic and Atmospheric Administration

- Light Detection and Ranging remote sensing data (LiDAR) Digital Elevation Model (DEM), 2016

Town of Stonington Planning Department

- Stonington Land Use

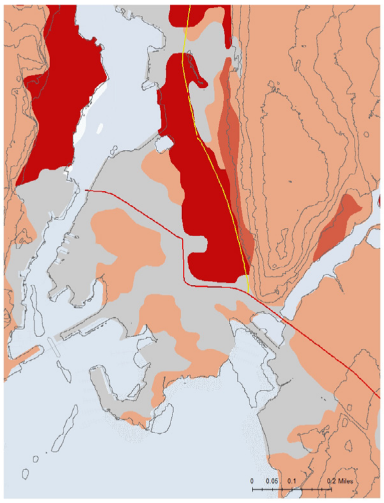
Drainage Channels



PREDOMINANTLY WELL DRAINING SOILS IN PROJECT AREA (P. 31)

CT DEEP:

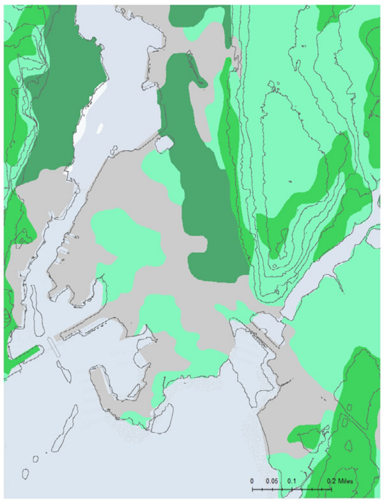
- Soil Drainage Class



SOILS SUITABLE FOR STORMWATER INFILTRATION SYSTEMS (P. 32)

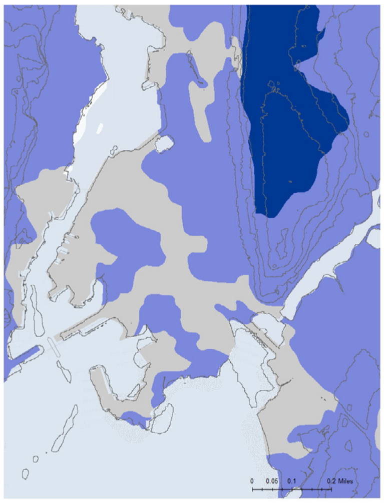
CT DEEP:

- Soil Survey Geographic (SSURGO) database SRM_INFILT attribute in the SOILS_POLY_DATA table.



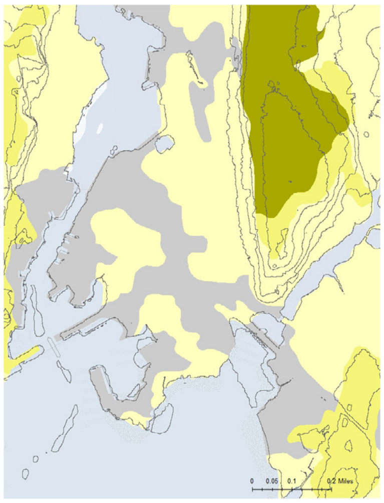
SOILS SUITABLE FOR PERMEABLE PAVERS (P. 32)

CT DEEP:
- Soil Survey Geographic (SSURGO) database SRM_PAVE attribute in the SOILS_POLY_DATA table.



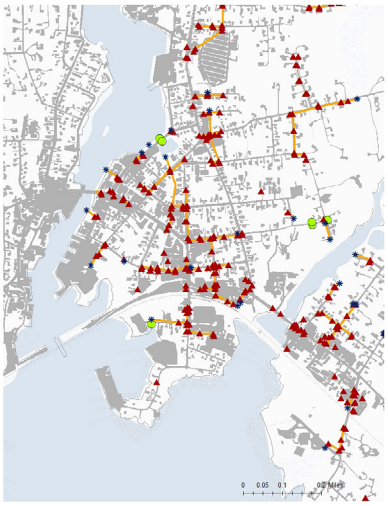
SOILS SUITABLE FOR WET EXTENDED RETENTION BASINS (P. 33)

CT DEEP:
- Soil Survey Geographic (SSURGO) database SRM_RETENT attribute in the SOILS_POLY_DATA table.



SOILS SUITABLE FOR DRY DETENTION BASINS (P. 33)

CT DEEP:
- Soil Survey Geographic (SSURGO) database SRM_DETENT attribute in the SOILS_POLY_DATA table.



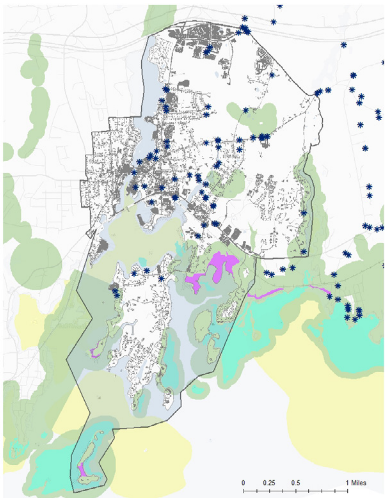
MUNICIPAL SEPARATE STORM SYSTEM IN MYSTIC (P. 39)

CT DEEP: Connecticut Environmental Conditions Online

- Impervious Surface 2012

Town of Stonington Planning Department

- Stonington Municipal Storm Sewer System (Drainage)



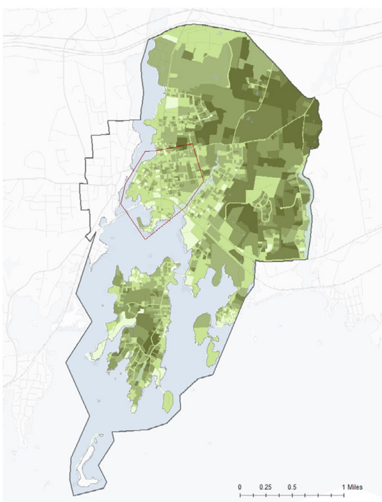
STORMWATER OUTFALLS AND WATER FLOW NEAR COASTAL HABITATS (P. 41)

Town of Stonington Planning Department

- Stonington Municipal Storm Sewer System (Drainage)

CT DEEP Connecticut Environmental Conditions Online

- Impervious Surface 2012
- Connecticut Natural Diversity Data Base Areas
- Connecticut Critical Habitats
- Eelgrass Beds 2012
- Shellfish Area Classification



PERCENT TREE CANOPY COVER IN DOWNTOWN MYSTIC (P. 45)

National Oceanic and Atmospheric Administration

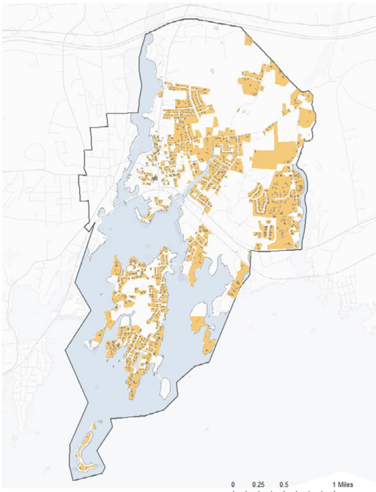
- Light Detection and Ranging remote sensing data (LiDAR), 2016

Town of Stonington Planning Department

- Parcels

CT DEEP Connecticut Environmental Conditions Online

- Connecticut Hydrography
- Impervious Surface 2012



SINGLE FAMILY RESIDENTIAL LAND USE AND IMPERVIOUS SURFACES (P. 79)

Town of Stonington Planning Department
- Stonington Land Use

CT DEEP Connecticut Environmental Conditions Online
- Impervious Surface 2012

Map Process

POLLUTION HOTSPOTS IN DOWNTOWN MYSTIC (P. 29)
HEAVY FLOW ACCUMULATION IN DOWNTOWN MYSTIC (P. 26)

Flow Accumulation
National Oceanic and Atmospheric Administration (NOAA)
- Light Detection and Ranging remote sensing data (LiDAR) - Digital Elevation Model (DEM) (Resolution: 3.28’ x 3.28’), 2016

1. Fill Sinks on DEM
2. Use ArcMap Flow Direction to generate flow direction layer
3. Use flow direction layer with ArcMap Flow Accumulation to generate flow accumulation layer
4. Reclassify to illuminate flow paths

Drainage Channels
National Oceanic and Atmospheric Administration (NOAA)
- Light Detection and Ranging remote sensing data (LiDAR) - Digital Elevation Model (DEM) (Resolution: 3.28’ x 3.28’), 2016

1. Fill Sinks on DEM
2. Use filled DEM with QGIS GRASS - r.watershed to generate Stream_Segments layer.
3. Use Stream_Segments to depict runoff drainage channels.

PERCENT TREE CANOPY COVER IN DOWNTOWN MYSTIC (P. 45)

National Oceanic and Atmospheric Administration (NOAA)
- Light Detection and Ranging remote sensing data (LiDAR) - Digital Elevation Model (DEM) (Resolution: 3.28’ x 3.28’), 2016

1. Subtract All LiDAR digital elevation model from Ground LiDAR digital elevation model to get a layer of just trees and buildings.
2. Reclassify new tree and building layer: 0-15=0, 15-100=1, 100+=0 to make a new layer that is just trees and buildings 15-100ft.
3. Reclassify Buildings2012 layer to binary.
4. Multiply reclassified buildings with trees and buildings using the raster calculator to get a new layer that is just trees 15-100 ft.
5. Clip new tree layer to Area of Interest.
6. To determine percent canopy cover, use tree layer based on parcel data.

Mystic is a historic village in southeastern Connecticut that is threatened by sea level rise, storm surge, and increasing amounts of precipitation as a result of a changing climate. In order to protect its residents, historic buildings, and community assets from these threats, the Town of Stonington is seeking to implement both shoreline and inland interventions.

This report assesses stormwater impacts in Mystic and recommends green infrastructure strategies that reduce and filter stormwater runoff. This report is intended to serve as a catalyst for future detailed site design projects, both in the village and in similar coastal communities.

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