Route 6 Stormwater and Vegetation Management Plan

DRAFT - July 22, 2016

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CAPE COD COMMISSION

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Image: Route 6 Westbound, just before the Sagamore Bridge

CHAPTER 1

INTRODUCTION

Route 6 Stormwater and Vegetation Plan

Project Background and Purpose

Route 6, or the Mid-Cape-Highway corridor, is a critical aesthetic gateway to the Cape and an environmental linkage that passes through a sensitive ecosystem directly impacting drinking water and coastal resources. Although the roadway has been updated and maintained over the years, much of the stormwater functions and vegetation management practices along the Route 6 corridor are guided by a system developed over 50 years ago. The additional volume of both cars and precipitation over the years continues to threaten local ecologies and water quality through contaminated runoff. The stormwater challenge is compounded by location on top of the Cape's sole source aquifer which produces over 80% of all public drinking water. The goal of this plan is to provide stormwater and vegetation management recommendations that keep the character and ecological structure of the corridor intact while providing a useful document that can steer management techniques from an ecological, human and environmental health perspective.

In the built environment of Route 6, many different site influences release pollutants that affect environmental quality. In addition to stormwater running over paved surfaces, emissions from cars and trucks can bind to form air pollution (particulate matter) that can move in air and later settle in dust that can be transferred into water bodies. The purpose of this report is to consider natural alternative technologies, phytoremediation concepts, and vegetation management approaches to improve the ecological functioning of stormwater and vegetation systems along the corridor while also considering aesthetics of this important gateway to Cape Cod. Stormwater Best Management Practices (BMPs) have the ability to mitigate nutrients and other contaminants such as heavy metals and petroleum compounds. The purpose of this report is to not only consider these BMPs to benefit water cleansing, but also to create layered multi-functional landscape that serves other ecological systems and enhances the built environment through an attractive gateway landscape for Cape Cod. The large scale ecological system of Route 6 is summarized within this document and suggestions to create site specific interventions that operate at many scales to benefit multiple systems are provided.

Included is guidance for Route 6 stormwater practices, native plant preservation and protection, strategic wildlife management, invasive plant control and roadway maintenance for the section of Route 6 between the Sagamore Bridge and the Orleans Rotary. The included recommendations meet the goals of the Cape Cod Commission's Regional Priority Plan and the 208 Water Quality Plan update while also considering the maintenance conventions and polices currently utilized at MassDOT in order to provide the greatest long term benefits. The goal of these recommendations is to encourage low impact changes in the corridor that enhance both ecological systems and scenic character.

Project Scope, Project Team & Methodology

The scope of this project covers the Route 6 right-of-way from the Sagamore Bridge to the Orleans/Eastham Rotary. For the purposes of this study, we identify segments of the roadway referred to by Exit number and delineated by east-bound (EB) or west-bound (WB).

The project team comprised of Offshoots, Horsley Witten Group (HW) and Professional Environmental Services (PES) combines the complimentary disciplines of landscape architecture, vegetation management (arborists) and civil engineering to provide a well-rounded existing conditions analysis and stormwater and vegetation recommendations for the corridor. Our team's methodology is described below.

Prior to beginning the assessment and fieldwork, our team compiled geo-spatial and cartographic data provided by the Cape Cod Commission (CCC) and the Office of Geographic Information (MassGIS). This data was used to determine the existing conditions and site constraints within the study area and included the Route 6 corridor boundaries, total study area in acres, length of roadway, surface cover types (i.e. impervious, woods and grass), topography, watershed boundaries, water bodies, wetlands soils, endangered species habitat, resources protection zones/buffers and general drainage patterns. We also relied on information and data collected as part of Horsley Witten's (HW) on-going stormwater improvement project with the Massachusetts Department of Transportation (MassDOT). HW has been working with MassDOT on the stormwater design evaluation of approximately 8.6 miles of Route 6 from the Orleans Rotary to Exit 9 in the Towns of Dennis, Harwich, Brewster and Orleans, MA. To date, HW has reviewed existing information, including the existing highway drainage system network and existing environmental conditions (e.g., topography, soils, etc.), and has conducted field assessments to evaluate potential for stormwater improvements. Preliminary evaluations of field data have been performed to identify stormwater retrofit opportunities as well as maintenance needs. This detailed work in the project area is timely and findings have influenced the recommendations provided within this document.

Following the data collection, project team members from Offshoots, HW, and PES completed a "drive-by" or "windshield" assessment of the Route 6 corridor from the Sagamore Bridge to the Orleans rotary. Elements that were observed during the assessment include: overall visual health of existing vegetation, representative plant communities, landscape features and location of existing stormwater management areas. The general assessment of existing conditions in the corridor is documented in Chapter 2 of this document.

Following the site analysis, recommendations for how beneficial stormwater practices can be prioritized along the corridor are provided in Chapter 3. A matrix of stormwater practice options best suited to the corridor and utilizing low impact development and phytoremediation techniques is provided to help prioritize sites and identify the most suitable practices for those areas. This work builds upon MassDOT work already completed for the area after Exit 9 towards the Orleans Rotary and considers stormwater practice types that will benefit plant communities, landscape aesthetics and other corridor functions.

Lastly, in Chapter 4, vegetation management strategies for long term maintenance are suggested to improve the corridor.


Image: Route 6 Eastbound, 1 mile before Exit 11

CHAPTER 2

SITE ANALYSIS

Route 6 Stormwater and Vegetation Plan

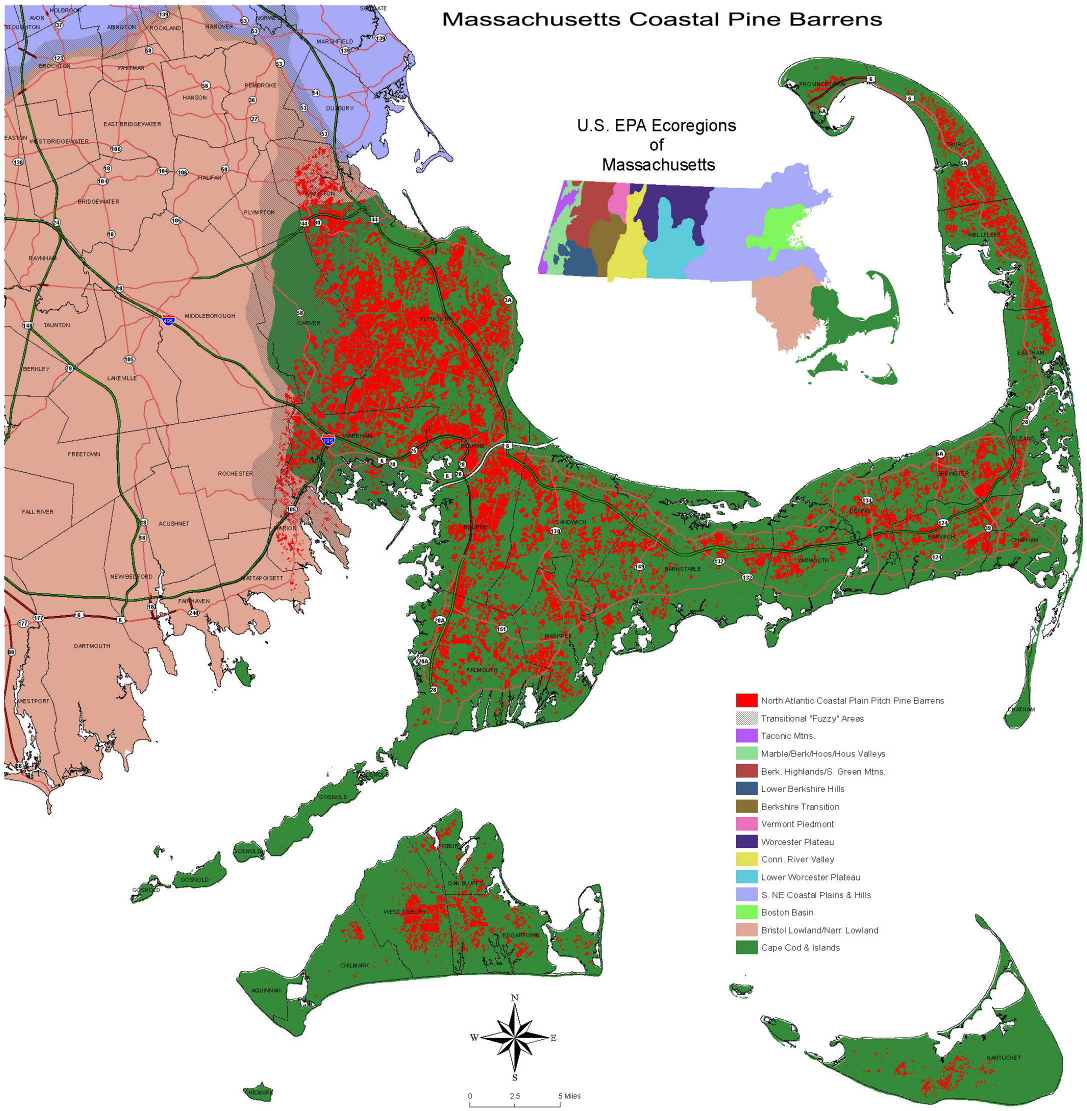
Existing Vegetation

The Route 6 corridor contains several plant communities ranging from disturbed landscapes of invasive species to mature Pine Barrens that represent a unique landscape of the coastal north-east from Cape Cod to southern New Jersey. Southeastern Massachusetts contains the second largest remaining Atlantic Coastal Pine Barren, just behind New Jersey's Pinelands. (SEMPBA) (Forman, 1998). The ecoregion between Duxbury and Provincetown, including the Route 6 Right-of-Way (ROW) is a diverse, dynamic but fragile Pine Barren region threatened by development. Arising from the most recent ice age, the coastal plain was left a sheet of sand, gravel and boulders on-top of bedrock, leaving behind the distinctive kettle-hole ponds, natural depressions and frost holes that are spotted throughout the Cape landscape. The Pine Barren (pitch-pine-scrub-oak forest upland ecosystem) is a designated plant community identified by the Massachusetts Division of Fisheries and Wildlife Natural Heritage and Endangered Species Program (NHESP) and it is a unique ecological condition, critical to preserve. This ecosystem paired with Route 6's positioning over the Cape's sole-source aquifer makes the stormwater and vegetation management discussion of critical attention for management and conservation.

WHAT ARE PITCH PINE/SCRUB OAK BARRENS?

Pitch pine/scrub oak communities are an open shrub-land plant community that occurs on outwash sandplains. These communities, also called Pine Barrens, typically have an open canopy of pitch pine and an often dense understory of scrub oaks up to 2-3 meters (7-10 feet) tall and shorter huckleberry/blueberry cover about a meter (3 feet) tall. A Pine Barren can consist of a canopy of 100 percent pitch pine or scrub oak or a combination of both. There is often a mosaic of pitch pine, scrub oak, heaths such as huckleberry, lowbush blueberry, and bearberry, broom crowberry, birds foot violet or lichen, which is the condition of much of the native vegetation along the Route 6 corridor. Pine Barrens are characterized by chemistry and acidity in the sandy soil systems. This causes the substrate to be extremely porous and although rainfall averages about 48 inches per year on Route 6, water drains very quickly. (USGS). Minerals such as nitrogen, phosphorus and sulfur travel through the soils leaving pine barren soils typically devoid of nutrients.

Pitch pine/scrub oak communities are not floristically very diverse; the combination of few species plus the physical structure of the vegetation defines the natural community. The main tree species is pitch pine (Pinus rigida) with the shrubs scrub oak (Quercus ilicifolia) dominant near the coast. The sands are acidic, nutrient poor and drought prone. In pitted outwash plains or rolling moraines, some low bowls, or kettles, are frost pockets and have more heath and lichen and less oak and pine. Deeper kettles that intersect the water table may have a Coastal Plain Pond.



WHAT IS HAPPENING TO THE PINE BARRENS OF SOUTHEASTERN MASSACHUSETTS?

Pitch pine/scrub oak communities change into other plant species types if there is no disturbance such as fire.

Barrens communities are dependent on periodic disturbance to prevent them from becoming overgrown by taller hardwoods such as black oak, white oak, black cherry, and shadbush. On Cape Cod, many former barrens communities have already reverted to upland forests because of the lack of periodic fire or other disturbances. Due to increased human habitation of Cape Cod over the last fifty plus years, fire suppression activities to protect communities from wildfires were increased thus allowing the closure of the tree canopies and the increased nutrient loading of the forest floor. These conditions are slowly changing the face of the forests type on Cape Cod. As noted on the map, the Pine Barrens as they exist today on Cape Cod are indicated in red.

Wildlife

WHAT ARE THE IMPORTANT WILDLIFE DIVERSITY SPECIES SUPPORTED BY A PINE BARREN?

Pine barrens support a diversity of birds, insects, reptiles and mammals many of which are on the Endangered Species list or the list of Species of Special Concern. Animals in the road corridor can be a safety concern for vehicles, but if properly managed, animals may also be able to safely use the corridor for habitat and connectivity between larger core habitat areas.

Pine barren birds:

- Eastern Towhee, Eastern Bluebird, Pine Warbler, Parie Warbler, Prairie Warbler and the Whip-poor-will.

Pine barren insects:

- Persius Duskywing, Frosted Elfin, Slender Clearwing Sphinx, Barrens Buck Moth, Melsheimer's Sack -Bearer Moth, Gerhard's Underwing, Barrens Tiger Beetle and the Antlion.

Pine barren reptiles:

- Northern Red-bellied Cooter
- Eastern Box Turtle
- Eastern Hognose snake

Pine barren mammals:

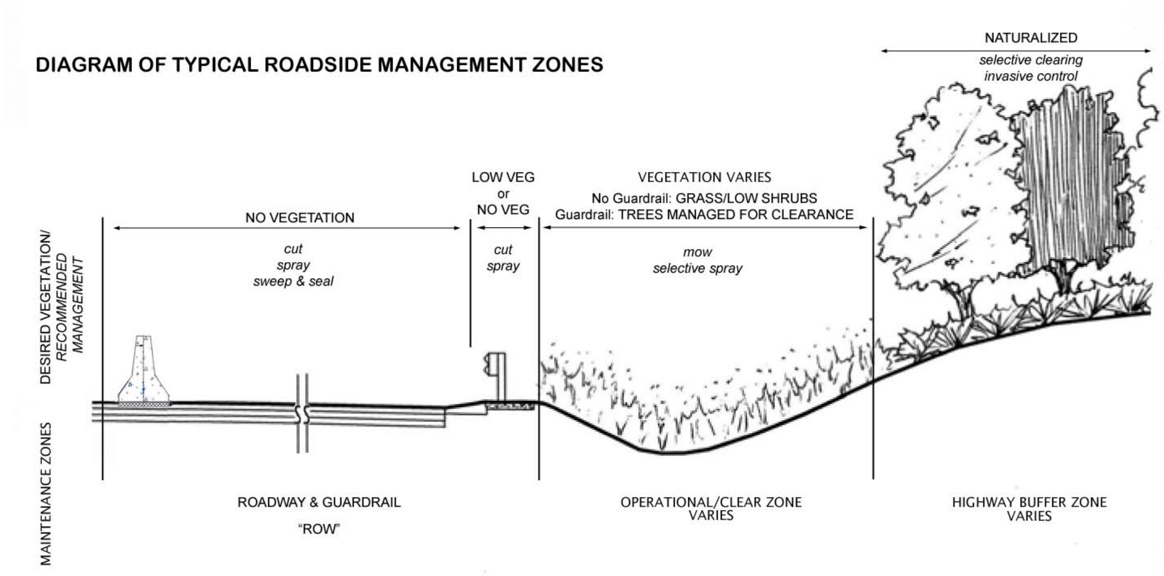
- Fisher- not necessarily restricted to pine barren landscapes, but were once completely eliminated from the state due to land clearing for agriculture and are finally beginning to move back. They find sustenance in many of the pine barren plant materials such as blueberries but preference squirrels, porcupines, mice, birds and fish. (Nature Conservancy)
- Cottontail rabbit

In addition to these species, there are a number of insects that support the unique habitat as well as some such as the gypsy moths which threaten the survival of tree species within the corridor. The widespread gypsy moth desecration of deciduous trees in Massachusetts in 2016 is a result of lack of rain in the spring which normally spurs a fungus keeping the moths in check. 2016 has been especially bad, as gypsy moths often stick to feasting on deciduous trees such as oaks, however, they have moved on to coniferous pine trees after eating their way through much of the deciduous forest cover. Trees are resilient to defoliation if they have time to recover in following years. However, if gypsy moths begin appearing in concurrent years, the Route 6 tree canopy could see a striking change in mortality that could be devastating to the landscape and ecology in the region.

It is important to think of the Route 6 corridor for desirable species but also as a potential conveyance of unwanted species as well.

Existing MassDOT Roadside Management

The Massachusetts Department of Transportation (Mass DOT) provides guidance through a Vegetation Management Plan that is updated every 4 years. The next update will be in 2018 and this document is an opportunity to provide recommendations to Mass DOT prior to that release. First and foremost, the agency's primary objective is to "provide safe use of and access to roadways, sidewalks and facilities and to preserve the integrity of highway infrastructure" (Mass DOT, 2014). However, the plan also notes the importance of providing stormwater control, habitat protection, controlling native plants and enhancing the scenic quality of the roadside. Mass DOT designated roadside vegetation into three primary zones. The Roadway and Guardrail Zone (ROW) is the area closest to travel lanes and containing guardrail, curbs, barriers and medians. It



is currently shown as low vegetation or no vegetation and herbicide is used frequently alongside mowing in this zone to keep vegetation from interfering with visibility. The next 20-30-foot zone is the Operation or Clear Zone which is typically mowed 2-4 times a year to maintain visibility of signage and provide space for errant vehicle recovery. Plant material is controlled if stem diameter can grow to greater than 4 inches and stormwater drainage and infiltration is often addressed in this zone. The Highway Buffer Zone extends from the clear zone to the edge of the right-of-way and the goal is to maintain and preserve a self-sustaining plant community, in the case of Route 6, the pine barren landscape. (Mass DOT, 2014).

If managements on Route 6 were to shift, the roadsides of the Route 6 corridor could provide a unique opportunity to re-stitch the unique pine barrens landscape of the Cape that is disappearing with development over time.

Existing Plant Communities

SAGAMORE BRIDGE TO EXIT 4

This section of roadway on Route 6 in both EB & WB directions is the most disturbed landscape within the study area in terms of vegetation analysis. From the bridge to Exit 2, the roadway is 4 lanes and approximately 200 feet wide with the median area around 30', which is a smaller median than most other areas of the corridor. As noted in the Route 6 Hydroplaning Crash Analysis, (CCC, 2013) there are occasional guard rails but the median was not designed for native plants to be retained or graded for any stormwater management. The area has the typical signs of disturbed landscapes, with invasive species, specifically knotweed, black locust, norway maples, tree of heaven, muti-flora rose and Japanese bittersweet creating a very sparse tree canopy of mostly invasives in the median and a thick cover of invasive understory plants in the Clear Zones. About 1 mile before exit 2, the tree cover gets a little denser in the median but the species are still showing signs of a disturbed landscape. The lack of berms and a narrow median in this area can be a problem for visibility with blinding headlights in either direction. Between exits 2 and 4, the landscape is characterized by pockets of trees alternating with large open swaths of minimal vegetation and wider medians 40-60 feet. It is also the location of overcutting performed by a MassDOT contractor in 2014 of approximately 2.5 acres within the 1.2-mile median segment. While 350 trees were replaced with evergreens, flowering and deciduous vegetation due to public outcry, the area remains disturbed, with many invasive species beginning to fill in with a lack of cover. A utility corridor passes over the highway right of way just after Exit 1C EB and again a few hundred yards later. Where the utility lines pass overhead, the species underneath are distinctly invasive due to repeat cuts and height management.

EXIT 4-9

This area was identified in the Hydroplaning Study as having a large number of wet weather crashes, the most occurrences happening between exits 5 and 6 in the EB direction. However, in terms of vegetation, we begin to see a more mature forested landscape, with representative pine barren species such as scrub oak, pitch pine and understory such as blueberry and huckleberry shrubs. The immediate roadway edges show loose aggregates and grasses. Mowing has kept the native understory from creeping out below the tree line. This area has very wide median areas ranging from 400-500 feet wide.

There are three utility corridor crossings in this section between Exit 5 and 7 in Hyannis, and a larger number of invasive species are present where these crossings occur.

EXIT 9-12

According to the hydroplaning analysis, the WB lanes between Exit 11 and 10 have widespread drainage issues that contribute to wet weather crashes. This area is in a narrow section between large wetlands and kettle hole ponds. There are also large clumps of invasives present- at mile marker 79 a large prevalence of knotweed on both sides. There is a utility crossing in North Harwich between exit 9 and 10 and the Cape Cod Rail trail passes over the highway a few hundred yards before exit 10.

EXIT 12- ORLEANS ROTARY

The section between exit 12 and the Orleans Rotary has similarities to the Sagamore Bridge to exit 4 section, in which disturbed invasive landscape species occur rather than native pine barrens species. This section is heavily populated with Robinia, around mile marker 89. When entering the rotary EB, there is a commercial property within close proximity to the road that is visible and would benefit from added vegetation for screening.

This section also includes several transmission line outlets which are mowed for maintenance by utilities but should be tied into any management plan with MassDOT. This area is also noted for its proximity to Cedar Pond, just before the Orleans Rotary to the South of Rt 6. The pond has faced a number of issues related to high nutrient content over the years, and sits adjacent to a mature Atlantic white cedar swamp. The latest issue is related to cormorants roosting on wires above the pond which has impacted water quality. Eversource is currently floating a plan to underground the wires that run over the pond at a cost of nearly $1 million which is being reviewed by the Town of Orleans and the Department of Environmental Protection. Entering the rotary, the inner landscape is overgrown and messy with many vine species and remnants of a more deliberate planting, with junipers, hollies and some grasses mixed in. The rotary center appears to show a depression and presents opportunities for both stormwater management and a gateway moment. Leaving the rotary and moving WB, there is significant Robinia mixed with grape, knotweed and scrub oak. In general, this section of the road corridor has a lot of species indicating a disturbed landscape with fewer native pine barrens species.

Above: Invasive species from top, Virginia Creeper and Norway Maple, Multi-flora Rose, Black Locust

Invasive Species Site Analysis

Mature pine barrens have the benefits of low nutrient content, low soil pH and low water holding capacity making it an undesirable habitat for most invasive plants. However, roadsides are prone to disturbance by nature and any fill materials, construction practices, erosion control, drainage interventions, especially the addition of lime and fertilizer make these areas highly susceptible to a shift in plant community toward invasive species.

Invasive species can spread along a roadway and even into a forest system nearby based on a number of factors. Wind can move seeds, as can birds and other animals that eat the seeds or catch them on their fur. In addition, substrates can be carried on vehicles or transported through drainage systems. In cold climates, road salt can actually perpetuate the growth of plants that are saline or salt adapted, changing from the natural systems that existed. Turbulence from moving vehicles can combine with natural wind or storm events to further move seeds around.

Disturbed areas near many of the on and off-ramps in the study area, utility lines and along cut areas of the median and highway show significant signs of invasive species becoming the dominant plant community. These species are typical of roadway disturbance and are found along corridors throughout the country.

ROBINIA

Robinia pseudoacacia (black locust) is an invasive hardwood tree in North America that is prevalent in disturbed areas along the Route 6 corridor and alters soil N cycling. It is a shade tolerant species native to the Central Appalachian and Ozark Mountains that is considered by many to be a detrimental invasive species on Cape Cod. One study found that even 14 years after Hurricane Bob destroyed Robinia populations on Cape Cod, they left a legacy of changes to soil N cycling. In coastal forests such as Cape Cod, higher soil nitrate concentrations and nitrification rates have potential to increase leaching and N loss to groundwater. The study also found that nonnative species richness was significantly higher with any present and former Robinia stands than in pine oak stands. The study concluded that nonnative species that lead to elevated nutrient levels increase the likelihood that other non-native species will invade the habitats. (Von Holle et al, 2013) In order to control these species and promote the preservation and reestablishment of the pine barren plant community, a suggested vegetation management plan is provided in Chapter 4.

National Heritage & Endangered Species Program (NHESP)- 13%

According to NHESP and published in the 13th Edition of the Massachusetts National Heritage Atlas (effective October 1st, 2008), there are approximately 185 acres (13% of the study area) of mapped Priority and Estimated Habitat within the study area, with the Estimated Habitat areas all overlapping the Priority Habitat areas. There are five different types of designated Priority Habitat areas and five different types of Estimated Habitat areas of state listed rare species in Massachusetts. The areas are located along the sides of the road within the ROW, from the Sagamore Bridge to exit 4, around the power lines corridor by exit 5, a strip between exits 6 and 7 and between Bass River and Kelley's Bay by exit 9. Any proposed projects occurring within these areas must be reviewed by NHESP for compliance with the Massachusetts Endangered Species Act (MESA) and its implementing regulations.

Tables 1 and 2- NHESP Priority and Estimated Habitat Areas within the Study Area

PRIORITY HABITAT	
PRIHAB_ID	**ACRES**
PH 359	24.96
PH 15	122.70
PH 1319	21.75
PH 1424	6.45
PH 1444	8.55
	184.42
ESTIMATED HABITAT	
ESTHAB_ID	**ACRES**
EH 19	**2.56**
EH 79	**122.70**
EH 144	**8.55**
EH 163	**11.72**
EH 217	**24.96**
	170.50

Stormwater Systems Site Analysis

The study area for the stormwater systems site analysis is slightly smaller than the overall project scope area, and includes the Route 6 Right-of-Way (ROW) corridor from the south side of the Sagamore Bridge extending to Exit 9. (The section of Exit 9 to the Orleans Rotary is currently being undertaken by HW as part of a separate study.) This section of Route 6 travels through five different towns, including, from west to east: Bourne, Sandwich, Barnstable, Yarmouth and Dennis. The highway through this section consists of a four-lane (two-lane each direction) east/west bound highway divided by a vegetated median of varying width and limited gravel and grass shoulders. A service road runs to

Above: National Heritage & Endangered Species along the Route 6 corridor the south of Route 6 within the ROW between exits 2 and 6 and the majority of White's Path is within the ROW between 8 and 9.

All of the statistics below are provided for this smaller scope area that consists of the following:

- 1,461 acres
- Approximately 23 linear miles of paved roadway
- 26% percent of impervious cover which is predominantly comprised of the roadway surfaces, but also includes approximately 12 parking lots, and some building roofs located within the ROW.
- The remaining area (74%) is comprised of the following:
  - 72.75% woods and grass
  - 1% wetlands
  - .25% water surfaces (ponds and rivers)

Watersheds

This section of the Route 6 corridor is located within eight different watersheds with the largest areas within the Barnstable Harbor, Bass River and Scorton Harbor watersheds. The remaining five watersheds include Sandwich Harbor, direct discharge to Canal South, Chase Garden Creek, Lewis Bay and Parkers River in order from largest to smallest. (See table 1)

The water bodies total approximately 3.58 acres within the corridor, with 2.81 acres considered impaired according to MassDEP's 2014 Integrated List of Waters. Bass River, Lewis Bay and Barnstable Harbor are listed as Category 5 impaired water bodies (Waters Requiring a TMDL) and Parkers River and Chase Garden Creek are listed as Category 4A (TMDL is completed). Furthermore, nitrogen loading threshold evaluations conducted through the Massachusetts Estuaries Program

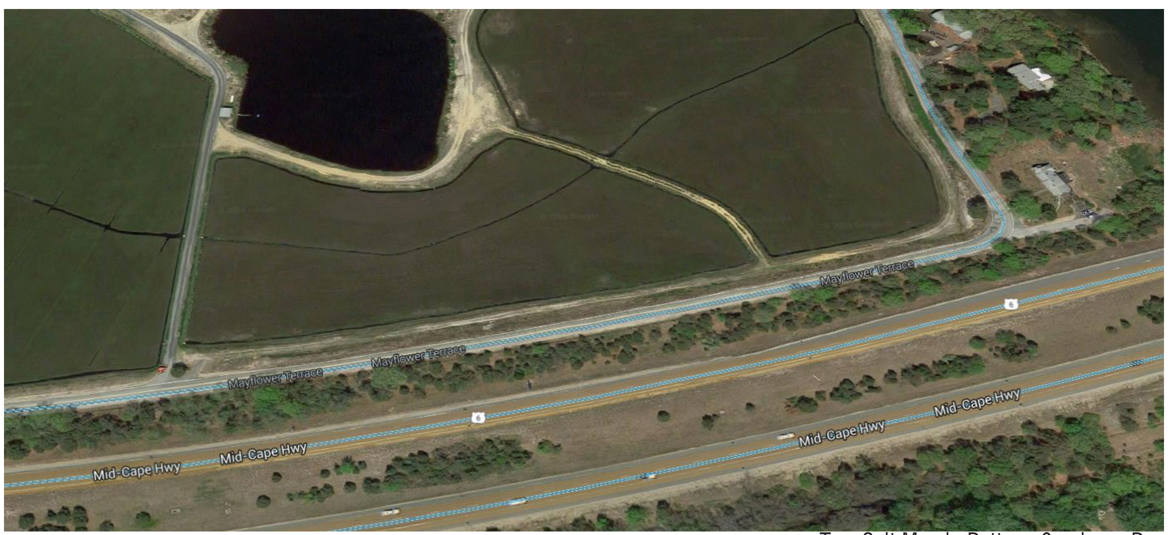
Table 3. Watersheds within Stormwater Study Area

MAJOR SYSTEM	MINOR SYSTEM	TOWN(S) IT INTERSECTS	ACRES WITHIN STUDY AREA	(TYPE OF) IMPAIRED WATERBODY WITHIN WATERSHED
MEP- Parkers River	Parkers River	Yarmouth	0.11	MassDEP Category 4A, MEP Nitrogen
MEP- Lewis Bay	Lewis Bay	Barnstable, Yarmouth	42.63	MassDEP Category 5, MEP Nitrogen
Chase Garden Creek	Chase Garden Creek	Dennis, Yarmouth	60.72	MassDEP Category 4A
Direct Discharge	Canal South	Bourne, Sandwich	100.92	
MEP-Sandwich Harbor	Sandwich Harbor	Sandwich	147.73	
MEP- Scorton Harbor	Scorton Harbor	Sandwich	233.05	
Barnstable Harbor	Barstable Harbor	Barnstable, Sandwich, Yarmouth	593.56	MassDEP, Category 5
MEP- Bass River	Bass River	Dennis, Yarmouth	278.72	MassDEP Category 5, MEP Nitrogen

(MEP) have indicated that Bass River, Lewis Bay and Parkers River all require watershed reductions of nitrogen to restore the estuarine systems.

Wetlands 1%

This section of the Route 6 corridor is comprised of 8 acres of wetlands (1% of the study area), which includes eight types of wetlands (See table 2). The majority of the wetlands acreage is located in the vicinity of exit 9. Between Kelley's Bay and the Bass River there is open water, salt marsh and coastal bank bluff or sea cliff. A section of Dinah's Pond and a small portion of coastal bank bluff or sea cliffs are just west of Kelley's Bay and a shrub swamp and a cranberry bog are along the edges of the roads west of Dinah's Pond. The remainder of the wetlands are small areas along the corridor that include a wooded swamp at exit 8, a shallow marsh meadow or fen at the Hyannis Golf Course between exits 6 and 7, a deep marsh and open water in the median between exits 5 and 6, a shallow marsh meadow or fen by exit 5, a deep marsh close to exit 5 and open water at exit 2.



Top: Salt Marsh, Bottom: Cranberry Bog

"Stormwater management plans for new development shall preclude direct discharge of

Table 4. Types of Wetlands within Study Area

TYPE	ACRES
Coastal Bank Bluff or Sea Cliff	1.996
Cranberry Bog	0.180
Deep Marsh	0.216
Open Water	3.582
Salt Marsh	0.791
Shallow Marsh Meadow or Fen	0.411
Shrub Swamp	0.557
Wooded Swamp Deciduous	0.244
TOTAL	7.976

untreated stormwater into natural wetlands and water bodies. New stormwater discharges shall be located a minimum of 100 feet from wetlands and water bodies." (Cape Cod Regional Policy Plan, 2012)

Soils

The majority of the soils in the study area are either excessively drained hydrologic soil group A or well drained hydrologic soil group B. Some very poorly drained D soils are located within the corridor, but comprise only 4 percent of the study area. The five major soils groups within the study area are Barnstable soils on the west portion from the Sagamore Bridge to mid-way between exits 5 and 6. Eastchop soils are predominantly located in the central portion of the study area between exits 6 and 7. Carver outwash plains soils are found on the eastern end between exits 7 and 9. Plymouth moraines are found sprinkled throughout the corridor in smaller patches in the western portion and larger portions around exits 6 and 7.

Vernal Pools-2%

There are approximately 33 acres (2% of the study area) of vernal pools, potential vernal pools, and their associated 350' buffer zones within the study area. Over 7 acres are located within the 350'

Table 5. Types of Soils within Study Area

NAME	DRAINAGE	GEOM DESCRIP	HYDROGROUP	ACRES
Barnstable	Well drained	moraines	B	522.15
Carver	Excessively drained	ice-contact slopes	A	96.01
Carver	Excessively drained	outwash plains	A	181.74
Dumps	NA	NA	NA	4.25
Eastchop	Excessively drained	outwash plains	A	133.48
Freetown	Very poorly drained	bogs	D	0.01
Ipswich	Very poorly drained	marshes	D	0.45
Pits	NA	NA	NA	0.79
Plymouth	Excessively drained	ice-contact slopes	A	4.22
Plymouth	Excessively drained	moraines	A	457.19
Plymouth	Excessively drained	outwash plains	A	0.36
Udipsamments	NA	leveled land	A	21.93
Urban land	NA	NA	NA	35.22
Water	NA	NA	NA	0.37
Water, saline	NA	NA	NA	2.51

Above: Soils along the Route 6 corridor

buffer zone of certified vernal pools and over 26 acres are within the 350' buffer of potential vernal pools. There is some overlap between the certified and potential vernal pool areas and three of the potential vernal pool areas are identified as various types of wetlands noted above. A portion of the Route 6 corridor at exit 2 is within a buffer zone for a certified vernal pool with the remainder located between exits 4 and 6, in close proximity to exit 5.

Vernal pools include those areas mapped and certified by NHESP as well as those areas identified in the field as eligible for certification by a professional wildlife biologist or other expert. Where a project site is located adjacent to a vernal pool, development shall be prohibited within a 350-foot undisturbed buffer around these resources. New stormwater discharges shall be located a minimum of 100 feet from vernal pools. (Cape Cod Commission Model Bylaws and Regulations and the Cape Cod Regional Policy Plan, 2012.)

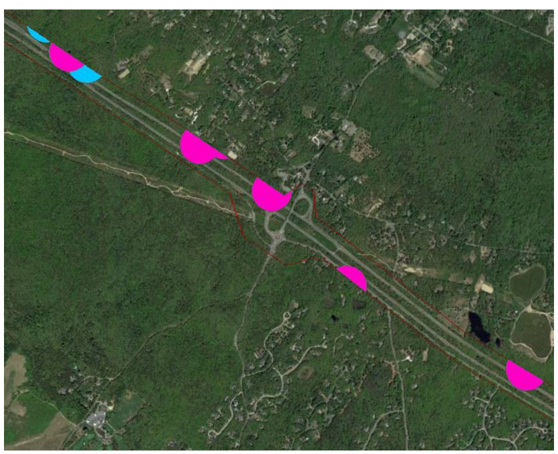
Wellhead Protection Zones-40%

There are approximately 588 acres (40% of the study area) of Wellhead Protection Areas within the study area which are comprised of three different categories of wellhead protection areas:

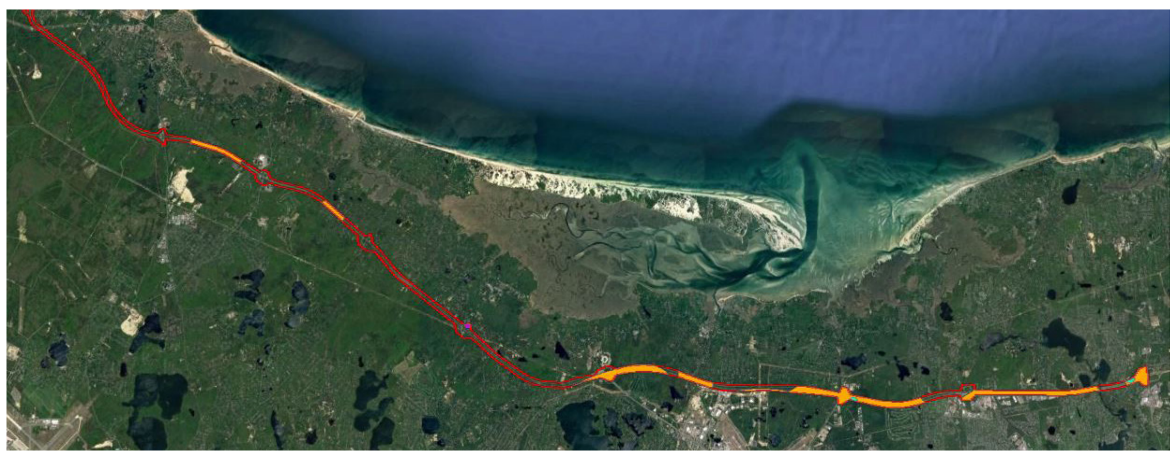
- Zone I - the protective radius required around a public water supply well or wellfield.
- Zone II - the area of an aquifer which contributes water to a well under the most severe pumping and recharge conditions that can be realistically anticipated.
- Interim Wellhead Protection Area (IWPA) - For public water systems using wells or wellfields that lack a Department approved Zone II, the Department of Energy and Environmental Affairs will apply an interim wellhead protection area.

(http://www.mass.gov/eea/agencies/massdep/water/drinking/water-supply-protection-area-definitions.html)

Within the study area there are 573 acres (39%) within a Zone II protection area, about 10 acres (.7%) in a Zone I and under 5 acres (.3%) in an IWPA . All of the Zone I areas within the study area are within either a Zone II area or an Interim Protection area. The Zone II wellhead protection areas are between exits 2 and 3, exits 3 and 4, and



Above: Vernal pools along the Route 6 corridor



Above: Wellhead protection along the Route 6 corridor much of the area between exits 6 and 9. The Zone I areas are a sliver between exits 3 and 4, and small areas at exits 5, 7 and 9. The only IWPA is at exit 5.

Topography

The topography along Route 6 is typically undulating beyond the relatively flat gravel or grass shoulder on the sides of the road. There are gentle sloping hills and depressions but also steeper climbs and drops off the main travel corridor. The width of the median ranges from approximately 15 feet to 300 feet between the Sagamore Bridge and exit 9. Typically the farther east, the wider the median. Within the median the topography is also gently undulating with small berms and depressions.

Existing Drainage

Top: Power lines disecting the Route 6 corridor Eastbound just after Exit 1C. Bottom: Typical median depression

HW's assessment of Route 6 between Dennis at exit 9 and Orleans at the rotary identified stormwater drainage infrastructure that consisted of closed drainage systems of catch basins and drainage pipes that discharged to outfalls within the ROW. Of the outfalls assessed, most (70%) discharged to natural depressions. Other sites generally discharged to paved asphalt swales (27%) that flowed to natural depressions; most paved swales appeared to be in good condition. Sedimentation and erosion were common at all observed outfalls; the intensity of scour generally increased with contributing drainage area.

Based on data available from the previous assessment, MassGIS, and drive-by and virtual site observations, we expect existing drainage infrastructure along Route 6 from the Sagamore Bridge to exit 9 to be similar to what HW has

Drainage flume and catch basins along the Route 6 corridor

observed, with the exception of the presence of a median which appears to capture a portion of the runoff. The drainage infrastructure visible along road throughout the study area consists of catch basins as well as paved flumes that direct runoff to depressions along the sides of the road and within the median via overland flow.

CHAPTER 3

STORMWATER MANAGEMENT

Route 6 Stormwater and Vegetation Plan

Approach

To effectively manage the impacts of stormwater and prevent adverse impacts to water quality, plant communities, flooding and habitat within the Route 6 Right-of Way, the following guidelines have been developed. These guidelines address each of the four items listed above through a series of steps that can be used as a screening process for selecting the best site-specific stormwater practice (or group of practices) for retrofits or new construction projects. The steps have been structured to first identify stormwater management goals beyond water quality, consider site constraints, and discuss operation and maintenance practices prior to selecting and designing a specific practice. This process will help to ensure that future projects will meet long-term goals and the vision for overall ecological improvements within the Route 6 Corridor.

Step 1: Site Classification

To maximize the cost-benefit of any proposed landscape and stormwater improvements within the Route 6 corridor, it is recommended that each potential site be analyzed to ensure that the best locations are selected for a stormwater retrofit practice. Once potential stormwater retrofit sites are located through field investigation and GIS-based data collection, it is suggested that each potential site be ranked using a two-step process. Step-one includes the categorization of each site by a four-tiered approach based upon the following criteria:

- Is the stormwater from the project area contributing to a direct or indirect discharge?
  - A direct discharge is a discharge that enters a waterway or wetland directly. Stormwater that directly discharges can carry pollutants directly to waterbodies without any chance for natural remediation. Therefore, elimination of direct discharges is critically important.
  - An indirect discharge is a discharge that will likely reach a waterway or wetland via overland flow or groundwater.
- Is the discharge to an impaired water body? Impaired water bodies are the greatest priority. Therefore, stormwater drainage areas impaired water bodies should take precedence over other waterbodies.
- What is the impaired water body pollutant of concern?
  - Nitrogen
  - Phosphorus
  - Other

The sites available for stormwater management within a project area should be categorized into four tiers as summarized in Table 1. Potential project sites meeting the Tier 1 or 2 criteria are considered the highest priority sites for stormwater practices to be implemented. It should be noted, in nitrogen-

Table 1. Four Priority Tiers		
TIER	**DISCHARGE LOCATION (Relative to waterbody or wetland)**	**IS RECIEVING WATER BODY IMPAIRED?**
1	Direct	Yes
2	Direct	No
3	Indirect	Yes
4	Indirect	No

sensitive areas, Tier 3 sites (indirect discharge) could be prioritized over a Tier 2 direct discharge sites.

Step 2: Selection of Stormwater Management Practices

Once a priority site has been selected in Step 1, the most appropriate stormwater management practice should be identified through a selection process outlined in the following Step 2 pages of this document. For the purpose of these guidelines, the stormwater management practices described in this section are divided into the following categories:

1. Existing Landforms
2. Wet Practices
3. Dry Practices
4. Filtration Practices

These four practice types were selected based upon the following criteria critical to the ecological success of the Route 6 corridor:

- Plant communities;
- Landscape aesthetics; and
- Potential habitat.

Although not every practice meets all of the criteria defined above (e.g. below ground recharge practices), each practice provides a different set of benefits which includes stormwater management, pollutant reduction, ease of maintenance, cost, scale, or ecological community creation. When properly located, designed, constructed and maintained, most of these practices can provide valuable native plant communities and thriving microhabitats as well as stormwater treatment. Therefore, the descriptions provided below focus on the micro-ecosystem created within each category. A more detailed description of the function, feasibility, design and maintenance of each practice can be found in numerous stormwater manuals and publications including the Massachusetts Stormwater Handbook (MassDEP, 1997) and the Rhode Island Stormwater Design and Installation Standards Manual (RIDEM & CRMC, 2010). For this reason, this document focuses on the specific benefits each of these practices might have on the overall ecological health of the Route 6 corridor, and creates a series of guidelines for how to achieve the greatest environmental benefit from these systems.

EXISTING LANDFORMS

Existing landforms refer to existing natural depressions or swales found in the surrounding landscape of Route 6 that can effectively be incorporated into a stormwater management system to hold, treat and infiltrate stormwater runoff. Both large and small depressions within the roadway corridor can be used to take advantage of natural drainage patterns and disconnect or intercept the road runoff prior to collecting into pipes and discharging to a constructed stormwater management practice or outfall. Depending on the site soil conditions and depth to the groundwater, natural depressions can function similar to either a dry or filtration practice as described below. The most important benefit of utilizing existing landforms along Route 6 is the minimal disturbance of the surrounding landscape, thereby, preserving existing plant communities and habitat as well as limiting the introduction of exotic invasive species during construction of a BMP. The amount of runoff directed to a depression should be in proportion to the receiving area to protect and maintain the existing ecological system and to ensure the site hydrology is not significantly altered. Sending large volumes of roadway runoff to one depression should be avoided to ensure the long-term health of the plant community and maintain the natural processes present within the depression. To maintain an overall healthy plant community and minimize disturbance during maintenance, upgradient pre-treatment practices, or a treatment train, must be incorporated into the system to capture sediment and other debris prior to discharge to the depression. When natural depressions are incorporated into a stormwater management system, existing exotic invasive species should be removed and supplemental plantings added to improve the surrounding plant community and habitat value. Native plants similar to those found within the landscape should be used with consideration to given to the additional plants recommended for the practices described below. Due to the preservation of the existing landscape, the use of natural depression can be a cost-effective approach to treat and manage stormwater management as well as restore and protect native plant communities.

WET PRACTICES

Wet practices can be used to both treat and manage stormwater generated from Route 6. These practices take advantage of shallow depths to groundwater to create a permanent pool or saturated zone, which provides treatment by the flow of stormwater and settling through the practice and the plant/soil treatment processes. They are suitable for sites with a shallow water table or locations abutting freshwater wetlands and include constructed shallow wetlands, gravel wetlands, and wet swales. They can vary in size from large constructed or gravel wetlands to smaller "pocket" wetlands created by wet swales. The permanent wet condition maintained in these types of practices help create a thriving wetland community, which can provide habitat for various indigenous species including plants, animals, amphibians, reptiles, insect and micro-organisms. Several rare and endangered species along the Route 6 corridor may benefit from newly introduced wetland conditions including several types of turtles. Due to these conditions, wet practices are considered to have a very high habitat value and can be effective in restoring native habitat.

Typical Cape Cod native plants for these practices are mainly herbaceous with some woody shrubs and occasional deciduous trees similar to a wet meadow plant community including Juncus effusus (Common Rush), Scirpus cyperinus (Woolgrass), Carex species (Sedges), Pontederia cordata (Pickerelweed), Vaccinium species (Blueberry), and Cephalanthus occidentalis (Buttonbush). Wet practices suitable for the Route 6 Corridor include the following:

CONSTRUCTED SHALLOW WETLAND

A shallow, wet, constructed system that provides water quality treatment primarily in a vegetated permanent pool. Constructed shallow wetland has the potential to provide the most biological diversity out of all the practices. It helps to create a wetland ecosystem, which serves as a home to numerous animal and plant species.

GRAVEL WETLAND

A constructed wetland that provides water quality treatment primarily in submerged, wet gravel bed with emergent vegetation. Although a gravel wetland can host many species, it would not provide the same surface material that some wetland species may depend on for survival.

WET SWALE

An open vegetated channel or depression designed to retain water or intercept groundwater for water quality treatment. A wet swale has the potential to create a small microhabitat for wetland species, but typically is unable to support the larger community that constructed wetlands would host.

DRY PRACTICES

Dry practices include both above and below ground practices that are designed to hold, treat, and infiltrate stormwater runoff. They are suitable for locations with well-drained, sandy soils and a deep water table. These practices can vary in size and include infiltration basins, infiltration trenches, recharge basins or dry wells and sub-surface chambers. They capture and temporarily store stormwater for short periods of time (typically 48 hours or less) and drain via infiltration through the soil and subsoil layers. They can be designed to hold varying amounts of collected stormwater both above and below ground and are effective in providing groundwater recharge. Due to varying depths and volume of stored stormwater runoff, as well as the fluctuation between dry and wet conditions, these practices typically do not provide as diverse a plant community and habit as wet practices. The plant communities established in these types of practices typically include highly drought tolerant species, which can survive occasional flooding and inundation for short periods of time. The plantings for above ground practices on Route 6 will vary from native trees, shrubs, perennials and grasses to create a more natural appearance, such as the depressions described above, to a mowed lawn/meadow appearance. Each depends upon the design, desired aesthetics and maintenance practices desired in a particular location. Native Cape Cod plant species that thrive in these practices are similar to those used in filtering practices and can tolerate both periods of drought and inundation such as: Schizachyrium scoparium (Little Bluestem), Morella pensylvanica (Bayberry), Viburnum dentatum (Arrowwood), Cornus sericea and Cornus racemosa (Red-Twig and Gray Dogwood) and Quercus bicolor (Swamp White Oak). Non-native but naturalized plant species include: Festuca rubra (Red Fescue), Panicum virgatum (Switchgrass), and Elymus virginicus (Virginia Wild Rye). Planting can also be a simple native low-mow or no-mow grass seed mixture that creates a meadow appearance and requires minimal ongoing maintenance. Most underground practices are also effective in providing ground-water recharge, which can be beneficial to the surrounding landscape. Proprietary sub-surface chambers can be used to create large below ground infiltration basins capable of handling large quantities of water. Although these underground structural practices provide little opportunity for habit or plant community creation within the actual practice, they do allow for the creation of above ground usable landscape areas, such as fields and meadows. However, trees and shrubs cannot be established in the area directly above or within ten feet of the belowground infiltration field. Dry practices suitable for the Route 6 Corridor include the following:

INFILTRATION BASIN

A constructed landscape depression designed to store the water quality volume or stormwater volumes from larger rain events to allow for infiltration into the underlying soils.

INFILTRATION TRENCH

An at or below ground infiltration practice that stores the water quality volume in the void spaces of a perforated pipe embedded in clean gravel allowing infiltration into underlying soils.

SUB-SURFACE CHAMBERS

A below ground n infiltration practice that stores the water quality volume in the void spaces of proprietary pre-fabricated chambers embedded in clean gravel allowing infiltration into underlying soils. Chambers can be placed under fields or lawn but are more frequently installed under pavement

RECHARGE BASIN

A below ground, open bottom, perforated concrete chamber of varying size embedded in clean gravel allowing infiltration into underlying soils. This practice is typically paired with a catch basin for pre-treatment.

FILTRATION PRACTICES

Filtration practices are used predominantly to treat stormwater runoff and not to manage increases in volume from larger rain events. They are suitable for locations with both shallow and deep water tables, varying types of soil, limited space, and where flooding is not a concern. These practices are typically vegetated shallow depressions or open channels, vary in size, and include bioretention areas, bioswales and vegetated sand filters. They use both vegetation and engineered soil matrices that can include soil, stone, organic matter or sand layers to provide treatment and can provide for infiltration/recharge or be underdrained. Due to shallow depth and volume of stored stormwater runoff, the fluctuation between dry and wet conditions and smaller area, these practices typically do not provide as a diverse a plant community and habit as the wet and dry practices. The plant communities established in these types of practices typically include highly drought tolerant species, which can survive occasional flooding, and minor inundation (3-9 inches of water) for short periods of time. Typical Cape Cod native plants for these practices include Panicum virgatum (Switchgrass), Iris versicolor (Blue Flag Iris), Schizachyrium scoparium (Little Bluestem), Rudbeckia hirta (Black-eyed Susan), and Cornus sericea (Red Twigged Dogwood), with a mix of what may be found in a wet meadow or grassland natural community. Depending upon the size of the practice and underlying soil conditions, trees can be incorporated into the planting mix. Native tree species for the

Route 6 corridor include Nyssa sylvatica (Tupelo), Acer rubrum (Red Maple), Quercus bicolor (Swamp White Oak), and Betula species (Birch). Filtering practices suitable for the Cape Cod Route 6 Corridor include the following:

BIORETENTION

A vegetated shallow depression that treats stormwater as it flows through a soil matrix, and is returned to the storm drain system, or infiltrated into underlying soils or substratum. A bioretention area can provide support for plant and animal species, but is limited to species that can tolerate the variable dry to wet conditions.

BIOSWALE

An open vegetated channel typically designed to hold, treat and convey smaller amounts of stormwater, while promoting filtration of runoff into an underlying manufactured soil matrix. A bioswale would host similar species to a bioretention area, but generally would support more grassland than wet meadow species due to its conveyance properties.

VEGETATED SAND FILTER

A filtering practice that treats stormwater by filtering stormwater through a vegetated surface or underground sand matrix. A sand filter would typically appear as more of a grassland community due to the well-draining sand matrix and would support animal species that thrive in that habitat.

Table 2-Optional Stormwater BMPs for the Route 6 Corridor		
GROUP	**PRACTICE**	**DESCRIPTION**
Existing Landforms	Depressions	Existing landforms refers to depressions created by the surrounding topography which can effectively be incorporated into a stormwater management system to hold, treat and infiltrate stormwater runoff
Wet Practice	Constructed Wetlands	A surface wet stormwater basin that provides water quality treatment primarily in a shallow vegetated permanent pool
	Gravel Wetland	A wet stormwater basin that provides water quality treatment primarily in a wet gravel bed with emergent vegetation.
	Wet Swale	An open vegetated channel or depression designed to retain water or intercept groundwater for water quality treatment.
Dry Practice	Infiltration Basin	A constructed landscape depression designed to store the water quality volume or stormwater volumes from larger rain events to allow for infiltration into the underlying soils.
	Infiltration Trenches	A below ground infiltration practice that stores the water quality volume in the void spaces of a perforated pipe and embedded in clean gravel allowing infiltration into underlying soils.
	Sub-surface Chambers	A below ground n infiltration practice that stores the water quality volume in the void spaces of proprietary pre-fabricated chambers embedded in clean gravel allowing infiltration into underlying soils.
	Recharge Basin	A below ground, open bottom, perforated concrete chamber of varying size embedded in clean gravel allowing infiltration into underlying soils.
Filtration Practice	Sand Filter	A filtering practice that treats stormwater by settling out larger particles in a sediment chamber, and then by filtering stormwater through a surface or underground sand matrix.
	Bioretention	A shallow depression that treats stormwater as it flows through a soil matrix, and is returned to the storm drain system, or infiltrated into underlying soils or substratum.
	Bioswale	An open vegetated channel or depression explicitly designed to detain and promote filtration of stormwater runoff into an underlying fabricated soil matrix.

SELECTION CRITERIA FOR STORMWATER TREATMENT PRACTICES

Upon completion of the site classifications, stormwater practices can then be selected for each Tier 1 and 2 site. A series of matrices are provided to be used as a screening process for selecting the best stormwater practice or group of practices for stormwater management within the Route 6 ROW. It also provides guidance for locating practices on each site. The matrices presented can be used to screen practices in a step-by-step fashion, based upon the following factors:

- Step 2a: Stormwater Management Capabilities
- Step 2b: Pollutant Removal
- Step 2c: Site Constraints
- Step 2d: Community and Environmental Benefit

The four matrices presented here are not exhaustive. Specific additional criteria may be incorporated depending on site location and project goals. Caveats for the application of each matrix are included in the detailed description of each. These matrices are provided as guidance to help choose the most appropriate practices for their given conditions.

STEP 2A- STORMWATER MANAGEMENT CAPABILITY

Use Matrix 2a to determine if a particular practice can manage a wide range of storms. For example, the filtering practices are generally limited to water quality treatment and seldom can be utilized to meet larger stormwater management objectives. This matrix examines the capability of each practice option to meet the following stormwater management criteria.

- Recharge. Does the practice provide groundwater recharge.
- Water Quality. Can the practice be used to provide water quality treatment effectively. For more detail, consult the pollutant removal table. (see Matrix 2b)
- Quantity Control. Can the practice be used for larger stormwater events and extreme flooding criteria.

Note: If a particular practice does not meet one of these requirements, it does not necessarily mean that it should be eliminated from consideration, but rather is a reminder that more than one practice may be needed at a site (e.g., a bioretention area and a downstream stormwater detention basin).

Matrix 2a- Stormwater Management Capability

GROUP	PRACTICE	RECHARGE	WATER QUALITY	FLOOD CONTROL
EXISTING LANDFORMS	Natural Depressions	● green	● green	● green
WET PRACTICES	Constructed Shallow Wetland	● red	● green	● green
	Gravel Wetland	● red	● green	● green
	Wet Swale	● red	● green	● red
DRY PRACTICES	Infiltration Trench	● green	○ red	○ green
	Sub-surface chambers	● green	○ red	○ green
	Recharge chamber	● green	○ red	○ green
	Infiltration basin	● green	○ red	○ green
FILTRATION PRACTICES	Sand Filter	○ yellow	● green	● red
	Bioretention	○ yellow	● green	● red
	Bioswale	○ yellow	● green	● red

● green: Practice generally meets this stormwater management goal.
● red: Practice can almost never be used to meet this goal.
○ red: Only provides water quality treatment if bottom of practice is in the soil profile
○ yellow: Provides recharge only if designed as an exfilter system.
○ green: Can be used to meet flood control in highly permeable soiles

STEP 2B- POLLUTANT REMOVAL

Use Matrix 2b to determine pollutant removal efficiencies for each practice. Select the practice with the highest removal efficiency for the targeted pollutant, based upon site classification. Matrix 2b outlines practice goals and restrictions based on the resource being protected. This set of factors involves screening out those practices that might contradict overall watershed protection strategies, or eliminating management requirements where they are unnecessary or inappropriate. Regulatory requirements under the Clean Water Act, TMDL reduction requirements and/or interests from watershed associations may influence the type, location, and design requirements for stormwater management practices.

The design and implementation of a stormwater management system is strongly influenced by the nature and sensitivity of the receiving waters. In some cases, higher pollutant removal, greater recharge or other environmental performance is warranted to protect the resource quality, human health and/or safety. Water resource areas include ground-water, freshwater ponds, lakes, wetlands, and coastal waters. Matrix 2b presents the key design variables and considerations that must be addressed for sites that drain to any of the above areas.

Matrix 2b- Pollutant Removal

GROUP	PRACTICE	MEDIAN POLLUTANT REMOVAL EFFICIENCY (%)			
		TSS	TP	TN	Bacteria
EXISTING LANDFORMS	Depression	See Infiltration Basin			
WET PRACTICE	Shallow Wetland	85%[2]	48%[3]	30%[2]	60%[2]
	Gravel Wetland	86%[3]	53%[1]	55%[3]	85%[2]
	Wet Swale	85%[3]	48%[3]	30%[2]	60%[2]
DRY PRACTICE	Infiltration Basin	90%[2]	65%[3]	65%[2]	95%[2]
	Infiltration Trench	90%[2]	65%[3]	65%[2]	95%[2]
	Subsurface Chambers	90%[2]	55%[2]	40%[2]	90%[2]
	Recharge Basin	90%[2]	55%[2]	40%[2]	90%[2]
FILTRATION PRACTICE	Sand Filter	86%[3]	59%[3]	32%[3]	70%[2]
	Bioretention	90%[1]	30%[2]	55%[2]	70%[2]
	Bioswale	90%[1]	30%[2]	55%[2]	70%[2,6]

"ND" Specifies No Data

"NT" Specifies No Treatment

References:

1. (UNHSC, 2007b)
2. (CWP, 2007)
3. (Fraley-McNeal, et al., 2007)
4. (prescribed value based on general literature values and/or policy decision)
5. (50% of reported values of low end for extended detention basins)
6. Presumed equivalent to bioretention; will require dilligent pollutant source control to manage pet wastes in residential areas.

STEP 2C- SITE CONSTRAINTS

Use Matrix 2c to determine if the soils, water table, drainage area, slope or head conditions present at a particular development site might limit the use of a practice. For example, constructed wetlands generally require a drainage area of 10 acres or more unless groundwater interception is likely, and can consume a significant land area.

This matrix evaluates possible options based on typical site constraints. More detailed testing protocols are often needed to confirm these conditions. The five primary factors that should be initially evaluated are:

- Soils. This column indicates if the practices is suitable for well, moderate or poorly drained soils. Initial evaluation of the soil conditions are based upon NRCS hydrologic soil groups at the site. Note that more detailed geotechnical tests are usually required for infiltration feasibility and during design to confirm permeability and other factors.
- Water Table. This column indicates the if a shallow (< 4') or deep depth (> 4') the groundwater is required. Note that a site soil evaluation and infiltration testing is required to determine the design depth the SHWT.
- Drainage Area. This column indicates the minimum or maximum drainage area that is considered optimal for a practice. If the drainage area present at a site is slightly greater than the maximum allowable drainage area for a practice, some leeway is warranted where a practice meets other management objectives. Likewise, the minimum drainage areas indicated for constructed wetland should not be considered inflexible limits, and may be increased or decreased depending on water availability (baseflow or groundwater), mechanisms employed to prevent clogging, or the ability to assume an increased maintenance burden.
- Slope. This column evaluates the effect of slope on the practice. Specifically, the slope guidance refers to how flat the area where the practice is installed must be and/or how steep the contributing drainage area or flow length can be without requiring retaining walls.
- Head. This column provides an estimate of the elevation difference needed for a practice (from the inflow to the outflow) to allow for gravity operation.

The criteria presented are planning level guidance and can vary depending upon, site conditions, budget and creativity.

STEP 2D- COMMUNITY AND ENVIRONMENTAL BENEFIT

Use Matrix 2d to compare the practice options with regard to maintenance, cost, plant communities, habitat, and gateway/aesthetic value. Some practices can have significant secondary environmental benefits that may meet specific site goals beyond stormwater management. Likewise, some practices have frequent maintenance and operation requirements that are beyond the capabilities of the owner. For example, infiltration practices are generally considered to have the highest maintenance burden because of a high failure history and consequently, a higher pretreatment maintenance burden and/or replacement burden.

A green circle indicates that the practice has a high benefit, and a red circle indicates that the particular practice has a low benefit.

- Operation and Maintenance. Practices are assessed for the relative maintenance effort needed for a practice, in terms of three criteria: frequency of scheduled maintenance, chronic maintenance problems (such as clogging) and reported failure rates. It should be noted that all practices require routine inspection and maintenance.

- Cost. The practices are ranked according to their relative construction cost per impervious acre treated. These costs exclude design, permitting, and other costs.
- Plant Community. Practices are evaluated on their ability to maintain certain plant community types.
- Habitat. Practices are evaluated on their ability to provide wildlife habitat, assuming that the proper plant communities are established. Objective criteria include size, water features, and vegetative cover of the practice and the surrounding area.

Matrix 2c-Site Constraints

GROUP	PRACTICE	SOILS	DEPTH TO WATER TABLE	DRAINAGE AREA (Ac)*	SITE SLOPE	HEAD (Ft)
Existing Landforms	Depressions	Native well drained to moderatly drained	>3'	Small to large	Varying slope	3 ft
Wet Practice	Constructed Shallow Wetland	Native poorly drained	<3'	Large *if not intercepting gw	Flat	3-5 ft
	Gravel Wetland	Native poorly drained	<3'	Medium to large *if not intercepting gw	Varying slope	3-5 ft
	Wet Swale	Native poorly drained	<3'	Small to medium *to any 1 inlet, not limit if runoff enters via sheet flow	Flat	1 ft
Dry Practice	Infiltration Trench	Native well drained to moderatly drained	>3'	Small to medium	Relatively Flat	1 ft
	Sub-surface Chambers	Native well drained to moderatly drained	>3'	Small to medium	Varying slope	1ft
	Recharge Basin	Native well drained to moderatly drained	>3'	Small	Varying slope	1ft
	Infiltration Basin	Native well drained to moderatly drained	>3'	Small to large	Varying slope	3ft
Filtration Practice	Sand Filter	Any soil type	< or >3'	Small to large	Relatively Flat	2-6 ft
	Bioretention	Any soil type	< or >3'	Small to medium	Relatively Flat	
	Bioswale	Any soil type	< or >3'	Small to medium	Varying slope	18 in-5 ft

Notes
Drainage Area: Small=<1 ac. Medium= 1-5 ac. Large= >.10 ac.
Slope: Flat: 0-2% Relatively flat: 2-5% Varying Slope 0-20%
*drainage area can be larger in some instances.

Matrix 2d Community and Environmental Benefit

GROUP	LIST	EASE OF MAINTENANCE	AFFORDABILITY	PLANT COMMUNITY	HABITAT	GATEWAY/ AESTHETIC VALUE
EXISTING LANDFORMS	Depression	🟡	🟢	🟢	🟢	🔴
WET PRACTICE	Constructed Shallow Wetland	🟢	🟡	🟢	🟢	🔴
	Gravel Wetland	🟡	🔴	🟡	🟢	🔴
	Wet Swale	🟢	🟢	🟢	🟡	🟡
DRY PRACTICE	Infiltration Trench	🔴	🟡	🔴	🔴	🔴
	Infiltration Chambers	🔴	🟡	🔴	🔴	🔴
	Recharge Basins	🟢	🟢	🔴	🔴	🔴
	Infiltration Basin	🔴	🟡	🟡	🔴	🟡
FILTRATION PRACTICE	Sand Filter	🔴	🔴	🟢	🔴	🟡
	Bioretention	🟡	🟡	🟢	🟡	🟢
	Bioswale	🟡	🟡	🟢	🔴	🟡

🟢 : High Benefit
🟡 : Medium Benefit
🔴 : Low Benefit

- Gateway/Aesthetic Value. Practices are assessed for their aesthetic value and appropriateness for use at identified gateways.

Step 3: Site Ranking

Upon completion of the practice selection, it is suggested that each site be subject to a refined ranking criteria to help further prioritize locations for potential stormwater management practices. Step two includes the further prioritization, which allows the identified sites to be compared to find the most cost-effective sites for implementation. Typically, the ranking system is based upon 100-point scoring system, where the relative merit of each potential site is evaluated by assigning points based on the following criteria.

- Existing landform is used
- Water quality volume treated
- Percent targeted pollutant reduction
- Corrects an existing flooding/safety problem
- Vegetation Enhancement
- Access issues (for construction and/or maintenance)
- Maintenance burden

The criteria outlined above are not listed in order of importance and the points assigned to each of the above criteria may vary by projects. For example, if the project site is located within a designated gateway area within the Route 6 corridor, vegetation enhancement may be assigned a higher value than the estimated planning level construction cost or water quality volume treated. The ranking criteria and weighted values should be developed in consultation with the Cape Cod Commission to ensure priority criteria properly address the project goals.

Based upon the assigned ranking criteria, number scores shall be assigned for each criteria and entered into a spreadsheet. It is suggested that the sites be ranked from highest to lowest to establish the priority list. Summing the assigned points for each of the factors provides an overall site score. Sites with the highest score represent the best overall candidates for implementation.

Step 4: Operation and Maintenance Goals

Prior to the selection of pretreatment practices for the top ranked sites, operation and maintenance goals should be considered. The type of maintenance required or desired could have a significant impact on the long-term ecological health of the potential plant communities and habitat, which may be created. For example, for a project site, which has identified habitat creation or preservation as a top priority, an above ground sediment forebay located within the practice may not be the best option since yearly continual clean out of sediment and disturbance will be require. A below ground oil and grit separator may be the preferred option to minimize future disturbance caused during regularly scheduled maintenance. The removal of sediment of debris from a below ground tank may be the preferred option to minimize disturbance to both plant communities and habitat.

Detailed Operations and Maintenance requirements of the different practices are provided the Appendix for reference. Additional text to be added.

Step 5: Design Elements for Pretreatment Practices

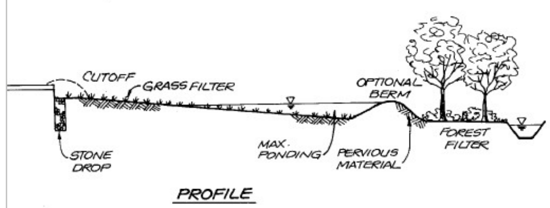
There are several stormwater management practices that do not meet the water quality performance Standard 3 and therefore cannot be used to treat the water quality volume, but may be useful to provide pretreatment. The incorporation of pretreatment practices into the stormwater management system can assist with the targeted pollutant removal, improve water quality and enhance the effective design life of practices by consolidating the maintenance to a specific location. Pretreatment practices must be combined with other stormwater practices and are not acceptable as standalone practices. The figures and images included in this section are schematic only. Design plans should be consistent with the schematic figures when using the method or practice described, but must be designed based upon site-specific conditions and construction purposes.

GRASS CHANNEL

Grass channels are similar to conventional drainage ditches, with the major differences being flatter side and longitudinal slopes, as well as a slower design velocity for small storm events. The best application of a grass channel is as pretreatment to other structural stormwater treatment practices (adapted from the CWP, 2008).

Grass channels can be applied in most development situations with few restrictions, and are well suited to treat highway or residential road runoff due to their linear nature. LUHPPL runoff should not be directed toward grass channels (particularly for pervious soils and shallow groundwater), unless they are lined to prevent infiltration.

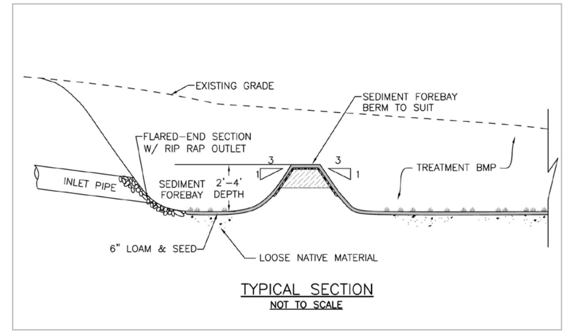
FILTER STRIPS



Source: Claytor and Schueler, 1996

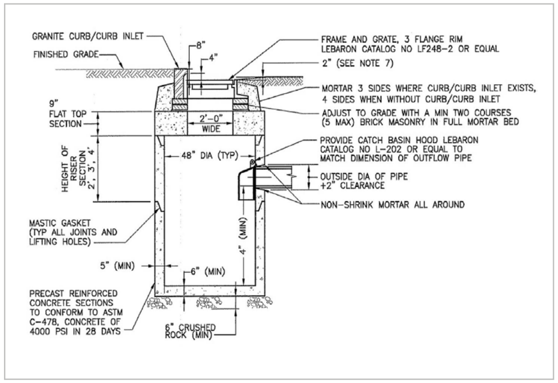
Filter strips (i.e., vegetated filter strips, grass filter strips, and grassed filters) are vegetated areas that are intended to treat sheet flow from adjacent impervious areas. Filter strips function by slowing runoff velocities and filtering out sediment and other pollutants, and providing some infiltration into underlying soils. Filter strips are well suited to treat runoff from roads and highways and with proper design and maintenance, filter strips can provide effective pretreatment. One challenge associated with filter strips, however, is that it is difficult to maintain sheet flow. Consequently, urban filter strips are often "short circuited" by concentrated flows, which results in little or no treatment of stormwater runoff (adapted from the CWP, 2008).

SEDIMENT FOREBAY



A sediment forebay can be used as a pretreatment device to minimize maintenance needs for stormwater practices. The purpose of the forebay is to provide pretreatment by settling out sediment particles. This will enhance treatment performance, reduce maintenance, and increase the longevity of a storm water facility. A forebay is a separate cell within the facility formed by a barrier such as an earthen berm, concrete weir, or gabion baskets.

DEEP SUMP CATCH BASINS



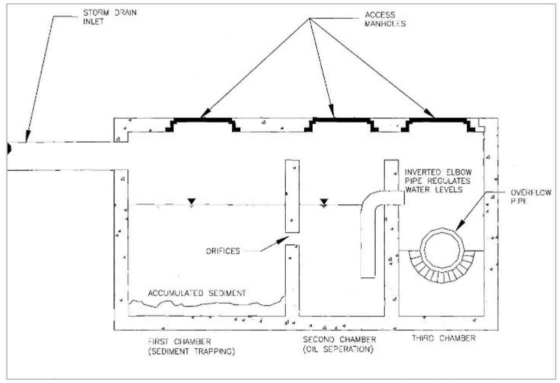
Source: MADEP, 2008

Deep sump catch basins are modified inlet structures that can be installed in a piped stormwater conveyance system to remove trash, debris, and coarse sediment. They can also serve as temporary spill containment devices for floatables such as oils and greases.

The deep sump catch basin must be designed in a catch basin-to-manhole configuration (NOT in a catch basin-to-catch basin configuration) to be used as pretreatment. The contributing drainage area to each deep sump catch basin shall not exceed 0.5 acres of impervious cover.

Potential site constraints include the presence of utilities, bedrock, and high groundwater elevations.

OIL AND GRIT SEPARATOR

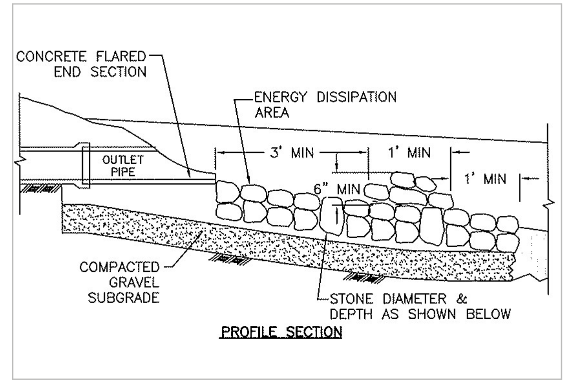


Source: MassDOT, 2004

Oil and grit separators can be used as a pretreatment device to minimize maintenance needs for stormwater practices. They are pre-cast concrete or pre-fabricated multi-chambered structures designed to remove course sediment, floating debris and oils from stormwater prior to discharge to a stormwater practice. They typically are used to enhance treatment performance, reduce maintenance, and increase the longevity of a storm water facility.

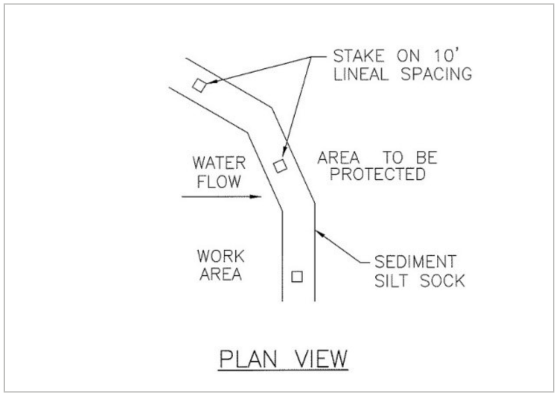
Each separator typically can be sized to receive runoff from a drainage area of less than 1 acre.

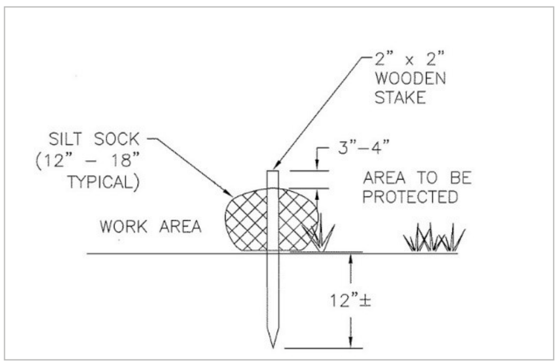
ENERGY DISSIPATION BASINS

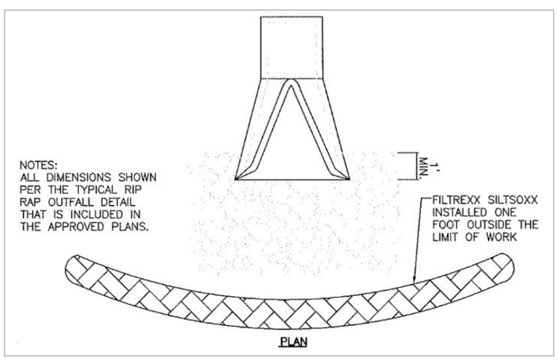


Energy dissipaters are pretreatment devices located at pipe outfalls use to protect downstream areas from erosion by reducing the velocity of flow and minimizing scouring. This practice is best suited for areas where site access for construction and maintenance would be such as natural depressions. Energy dissipaters could also be applied at existing outfalls into natural depression to stabilize the area around the outlet and reduce erosion and sediment build up within the surrounding landscape.

COMPOST FILTER SOCKS







Compost filter socks are recommended as a practical, temporary solution for areas where site access for construction and maintenance are difficult such as outfall locations. They can be easily designed and installed based on site requirements and have the following benefits:

- Reducing energy of runoff at the outlet and slowing velocity of flows on slopes;
- Filtering of stormwater runoff, including reduction of sediment, nutrients, bacteria, heavy metals and petroleum hydrocarbons; and
- Improving potential maintenance requirements by removing the silt sock at the end of its design life or incorporating the compost sock as a natural berm at the site.

A typical detail for a compost filter sock is shown in Figures 4 and 5. Compost filter socks are typically 12- to 18-inches in diameter and are staked in place (either through center as shown or on the downhill side) to ensure that flows do not move them. Compost filter socks may also be seeded at the time of installation to increase pollution filtration and restoration at the outfall.

PROPRIETARY DEVICES

Many proprietary stormwater treatment devices are available and may provide a cost-effective solution, particularly for retrofit situations, including oil/grit separators, hydrodynamic devices, and a range of media filtration devices, among others. Studies (Schueler, 2000; Claytor, 2000; UNHSC, 2007) have shown that these proprietary devices are not capable of achieving the required water quality performance and there is insufficient documentation to use these practices as stand-alone devices. However, they may provide pretreatment for stormwater before it is directed to a water quality practices if an independent third-party monitoring group (e.g., MASTEP, ETV, TARP) verifies that it is capable of a minimum of 25% TSS removal efficiency. Oil/grit separators are particularly useful pretreatment practices for runoff that may have high pollutant loads of oils and grease.

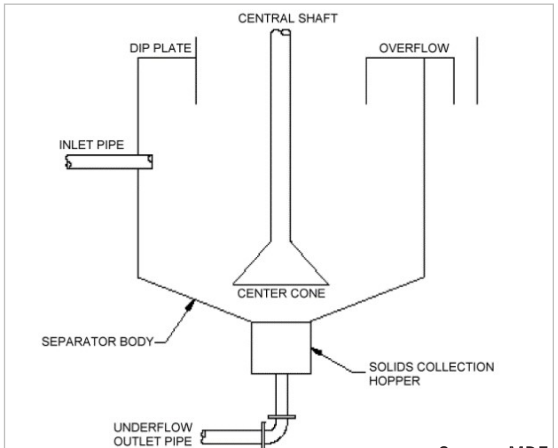
To qualify as an acceptable pretreatment device, a proprietary device must remove a minimum of 25% TSS, as verified by an independent third-party monitoring group. In certain retrofit cases where higher pretreatment standards may be appropriate, higher removal efficiency for TSS may be required in order to achieve stormwater treatment goals for the project.

In order to be used for pretreatment device, proprietary devices are designed, per the manufacturer's recommendations, as off-line systems or to have an internal bypass to avoid large flows and re-suspension of pollutants.

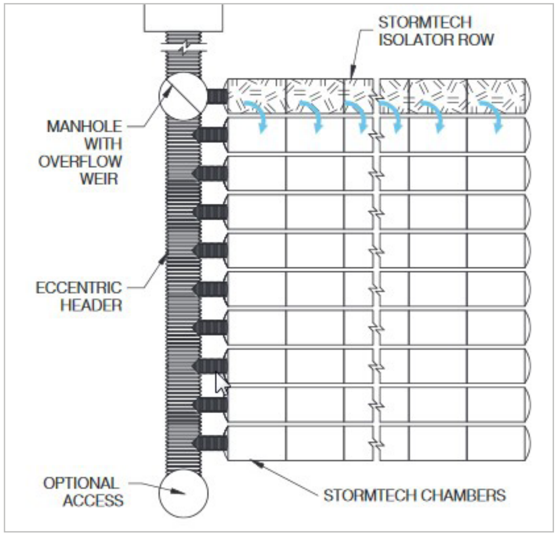
The contributing drainage area to each proprietary device should generally not exceed 1 acre of impervious cover. Potential site constraints include the presence of utilities, bedrock, and high water tables.

Hydrodynamic separators are small, flow-through devices that treat runoff by trapping sediment and debris and by separating floatable oils from the water. These devices primarily rely on a swirling action and particle setting to remove sediment and other pollutants. Hydrodynamics separators generally work best as pretreatment devices for other stormwater management practices such as bioretention areas or infiltration basins.

The Isolator Row is a manufactured system designed to provide subsurface water quality treatment and easy access for maintenance. It is typically used to remove pollution from runoff before it flows into unlined sub-surface infiltration chambers designed for detention and water quantity control. The Isolator Row consists of a series of chambers installed over a layer of woven geotextile, which sits on a crushed stone infiltration bed surrounded with filter fabric. The bed is directly connected to an upstream manhole for maintenance access and large storm bypass. The Isolator Row is well suited for locations where subsurface chambers are used and above ground pretreatment space is limited.



Source: MDE



Source: StormTech

Pretreatment Companion Practices									
GROUP	LIST	GRASS CHANNEL	FILTER STRIP	SEDIMENT FOREBAY	DEEP SUMP CB	OIL/GRIT SEPARATOR	ENERGY DISSIPATOR	COMPOST FILTER SOCK	PROPRIETARY DEVICES
EXISTING LANDFORM	Depression	Yellow	Red	Red	Green	Green	Green	Green	Red
WET PRACTICE	Constructed Wetland	Green	Yellow	Green	Yellow	Green	Red	Red	Red
	Gravel Wetland	Yellow	Red	Yellow	Yellow	Green	Red	Red	Red
	Wet Swale	Green	Green	Green	Yellow	Yellow	Red	Red	Yellow
DRY PRACTICE	Infiltration Trench	Yellow	Green	Yellow	Green	Red	Red	Red	Red
	Infiltration Chambers	Yellow	Yellow	Red	Green	Green	Red	Red	Green
	Recharge Basins	Red	Red	Red	Green	Green	Red	Red	Yellow
	Infiltration Basin	Green	Red	Green	Yellow	Green	Red	Red	Yellow
FILTRATION PRACTICE	Sand Filter	Green	Red	Green	Yellow	Yellow	Red	Red	Yellow
	Bioretention	Green	Red	Green	Yellow	Yellow	Red	Red	Yellow
	Bioswale	Green	Yellow	Green	Yellow	Yellow	Red	Red	Yellow

Green: Best option for most practice and site conditions
Yellow: Good-may depend upon the size of the practice, contributing watershed and site area
Red: Not practical, but could be used in certain applications.

CHAPTER 4

VEGETATION MANAGEMENT

Route 6 Stormwater and Vegetation Management

Approach

This plan recommends that the unique Pine Barren ecosystem crossed by the Route 6 corridor should be maintained as Pine Barrens by MassDOT. The following defines the significance of Pine Barrens to the Cape Cod geographical and ecological area and the management tools that could be considered by the MassDOT to perpetuate and in some areas reestablish these Pine Barrens.

Currently The Massachusetts Department of Conservation and Recreation, Camp Edwards Military Reservation, Wampanoag Indian Reservation, Trustees of Reservations and the Nature Conservancy along with municipalities are doing their part to actively manage the Pine Barrens of Southeastern Massachusetts as they are impacted by their organizations.

WHAT ARE THE EFFECTIVE MANAGEMENT TOOLS TO MAINTAIN AND INCREASE THE EXISTANCE OF PINE BARRENS ON CAPE COD?

Pitch pine/scrub oak communities are a fire maintained and fire dependent type of natural community. Species of the community tend to be adapted to occasional light fires: scrub oaks and huckleberries sprout readily from their root crowns and pitch pine has thick bark that resists fire damage and produces some cones that release their seeds only when heated by fire. Once the fire has passed these species sprout back vigorously while most types of trees don't survive the fire. Some of the herbaceous species have seeds that stay in the soil for years and germinate after light fire; the plant may be abundant for a few years after a fire before larger plants shade them out. A pulse of nutrient availability after a fire results in lush growth of the plants in the first few years, with increased variety of insects that eat the plants, and birds that eat the insects and berries of the plants.

Prescribed burns that remove accumulated dead needles and leaves on a regular basis help maintain the natural community and reduce the danger from wildfires.

PRESCRIBED BURNING

Historically, pine barren landscapes are prone to wildfires given their unique composition and many of the early inhabitants used controlled burning to maintain the ecosystem stability (Nature Conservancy). However, fire suppression has been used with today's denser settlement causing pine barrens to become thicker with vegetation such as shade- tolerant hardwoods, transitioning to species such as Pinus strobus (White Pine). The lack of more frequent burns has actually put communities at higher risk for a larger uncontrolled wildfire and with species crowded in due to lack of controlled burns, this creates more fuel which has repercussions for person and property.

Fire risk is categorized by fuel types, and the pitch pine and scrub oak cover in Southern Massachusetts is considered high. However, one way to control wild fires is actually through controlled burning. There are two examples of large pine barren forest cover in Southern Massachusetts that use this technique: Myles Standish State Forest in Plymouth and the Massachusetts Military Reservation in Bourne and Sandwich.

Massasoit National Wildlife Refuge is a piece of the Myles Standish state forest and part of the largest contiguous pitch pine scrub oak forest north of Long Island Sound. Controlled burns have been held in this area for the past several years, with targets on underbrush such as needles, fallen twigs and leaves and are carefully managed. Controlled burns in this area are mainly to protect the communities by reducing the fuel that could ignite larger fires. Myles Standish State Forest began their controlled burn program in 2000 and Massasoit began shortly thereafter in 2007.

Outreach and educating the public regarding fuel-hazard reduction and planning must be addressed prior to any changes in forest management. Prescribed burning has been shown to be supported more strongly when the public understands the techniques involved. (CITE). Strategies could include information distribution such as fliers, public meetings or television ads, but a demonstration project could have the potential to reach a wider public audience. In addition, educating homeowners on defensible space techniques followed by more stringent regulations on buffer zones for new development.

Controlled Burning in combination with mechanical reduction is a key Pine Barren vegetation management tool.

Any control burn needs to be carefully planned and prepared for and should involve other entities besides MassDOT in the planning, preparation and implementation phases. Organizations that should be involved should include but not necessarily limited to; Municipal Fire Departments, Massachusetts Department of Conservation and Recreation Fire Control, Nature Conservancy, Natural Heritage & Endangered Species Program,

Division of Fisheries & Wildlife and local Conservation Commissions.

A Resource Management Plan should be developed utilizing the expertise of the aforementioned entities and should include:

1. Develop and implement a comprehensive fire management program to include a combination of mechanical fuel reduction and prescribed fire to improve and maintain habitat quality for rare Pine Barrens species, as well as to reduce the potential for an uncontrollable wildfire.
2. Develop and implement a plan to remove tree plantations consisting of non-native species to reduce fire danger and improve Pine Barrens habitat. Following cutting, controlled burning should be implemented to stimulate development of native Pine Barren habitat.
3. A timetable for the mechanical removal of undesirable plant species that will eliminate any potential for impact on other wildlife habitat and define the extent of the mechanical removal operation which should coincide with the control burn area.
4. A timetable for the Control prescribed burn that will eliminate any potential for impact on other wildlife habitat and define the extent of the annual burn.

A recommended mechanical fuel reduction method is the utilization of a brontosaurus. An advantage to using a brontosaurus is that it has tracks rather than wheels, so it doesn't compact the ground or do as much damage to low-growing plants as a wheeled vehicle would. The brontosaurus can make a trail into an area, then reach out 30 feet on each side with its boom – which ends in a tooth-studded drum spinning at high speed – and reduce standing trees and shrubs to scattered shards of wood and bark. (Doing this work in winter avoids harming box turtles and other reptiles that hibernate underground. Also, birds and mammals aren't breeding at that time.)

Fire then follows, and a functioning pine barrens is reborn. In the future, controlled burns will periodically consume fallen branches and other debris, reducing fuel loads on the ground and lowering the risk of dangerous, out-of-control crown fires in this region.

OTHER MANAGEMENT TACTICS

MOWING

There are two dimensions that should be considered when using mowing as a management tactic: timing and frequency. (Forman, 2003). Timing depends on season, nesting periods, pollination and unexpected extreme weather events such as droughts or heavy rains. It is well documented that mowing once or twice a year is a large cost savings to say 5 or 6 times a year. It also provides more opportunity for species richness in not favoring a few species that begin to outcompete others. There is also concerns for soil erosion with repeated mowing, especially on slopes exceeding 3 on 1 slopes. Reduction in mowing practices in both time and scale can have profound effects on both ecological systems and cost. It has been documented that mowing twice a year in the beginning and end of growing cycles yields the highest plant diversity (Forman, 2003).

Typically, on roadsides, there is a variety of resistant plant species within the ROW that receive significant exposure to both vehicular toxins and maintenance regimes. Grass species have growing cells on the base of their stems, stimulating growth from mowing. However, other herbaceous species such as forbs have growing cells at the tip of their stems, hence, cutting and mowing can have serious effects on the roadside environment of native species. (Forman, 2003). Thriving roadside species have wide adaptability to disturbance, are usually prone to full sun and don't seem too effected by wet/dry or cool/ hot changes. Most plants are predominantly perennial with some annual species spread from seed. (Forman, 2003). Natural plant communities can and are often seen along roadsides, however, on over-mowed sites and those where nonnative plants surround the corridor, these plant communities can become lost. In a worst case scenario, monocultures of invasives or mowed grasses can form along roadsides. This type of habitat is early successional, and mowing practices and other types of human impacts keep this succession from moving past the herbaceous perennial stage. Paired with construction activities and repeated mowing, soils are fundamentally altered, often increasing soil pH or nutrients. These disturbance practices directly preference nonnative species. (Van Clef, 2009). In addition, roadsides are highly compacted by vehicles and heavy maintenance machinery. In many cases herbicides are used to break down woody plants or plants are used strategically as noise barriers, glare reducers and impact absorption for errant vehicles. (see MassDOT regulations). All of these vegetation practices greatly impact the native plant environment.

Additional text to be provided in future drafts.

Operations and Maintenance

The maintenance objective for these practices includes maintaining the hydraulic and pollutant removal capacity of the systems and maintaining healthy native, vegetative cover. This section describes the required O&M measures for each practice. This information is provided as an appendix so that maintenance goals can be considered during the practice selection process.

During the six months immediately after construction, all stormwater practices require monthly inspection as well as after precipitation events of at least 1.0 inch to ensure that the system is functioning properly. The following activities are recommended during the first six months after construction for all types of stormwater practices:

- Inspection of flume inlet, sediment forebay weir, and side slopes for erosion gullying. Repair/re-vegetate as necessary.
- Proper grass seed establishment and satisfactory growth. Additional loam and overseeding may be required within the first 6 months to correct bare spots and thin growth.
- Watering as required to establish and maintain new plantings.
- Loam and seed any void areas or washouts along swale and infiltration beds caused by precipitation runoff.

Thereafter, inspections should be conducted on an annual basis and after major storm events, which are those greater than or equal to the 1-year, 24-hour (Type III) precipitation event (~2.5" in Barnstable County).

The following tasks are recommended as specified or as needed basis and broken down by practice type.

NATURAL PRACTICE

Additional text to be added here in future versions

WET PRACTICES

CONSTRUCTED WETLAND

- Additional text to be added here in future versions

GRAVEL WETLAND

- Additional text to be added here in future versions

WET SWALE

Wet swales should be inspected annually and after storms of greater than or equal to the 1-year precipitation event. During inspection, the structural components of the system, including check dams, and overflow spillway structures, should be checked for proper function. Maintenance work consists of the following:

- Trash and debris should be removed and properly disposed.
- Sediment should be removed from the bottom of the swale.

- Any clogged openings should be cleaned out and repairs should be made where necessary.
- Embankments should be checked for stability, and any burrowing animals should be removed according to State or local Animal Control requirements.
- Vegetation along the side slopes should be mowed annually.
- Woody vegetation along those surfaces should be pruned where dead or dying branches are observed, and reinforcement plantings should be planted if less than 50 percent of the original vegetation establishes after two years.

DRY PRACTICE

INFILTRATION BASINS AND TRENCHES

An infiltration basin is a shallow impoundment that is designed to treat and infiltrate stormwater into the soil. These basins are sized to provide storage and exfiltration for recharge volume and treatment for water quality. Infiltration basins are designed to

Wet Swale Maintenance Schedule		
GENERAL MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Site Inspection	Min.once per year & after major storm events	Spring thru Fall
Debris removal	Min.once per year & after major storm events	Spring thru Fall
Sediment removal	Min.once per year or when sediment is > 3" in stone-lined swale/ sediment forebay; Ensure sediment does not cause blockage of flume inlet	April
LANDSCAPE MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Mowing	Min. twice per year or as necessary. Maintain 4"-6" grass height	Spring thru Fall
Watering	Drought conditions only	July- August
Overseeding	As required	Spring or Fall preferred
Fertilizing	Not required	
FILTER BED MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Tilling	As needed	If standing water does not drain after 48 hours
Soil Media Replacement	As needed	If standing water does not drain after tilling (see above)
Snow Removal	Not required	Not required

maximize pollutant removal efficiency, and can also help recharge the groundwater, thus restoring low flows to stream systems. They also attenuate peak discharges.

- Remove materials deposited along the basin floor (e.g., trash and litter) manually on a quarterly basis.
- Correct side slope erosion gullying, animal burrowing or slope slumping, and replanting as necessary.
- If standing water is observed more than 48 hours after a storm event, perform the following steps:
  - Aerate the basin floor
  - If aeration does not work, remove the top 12 inches and replace with new soil. If discolored or contaminated material is found below this removed surface, then remove and replace material until all contaminated sand has been removed from the filter chamber. Dispose of the soil in accordance with all applicable federal and local regulations.

Infiltration Basins & Trenches Maintenance Schedule		
GENERAL MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Site Inspection	Min.once per year & after major storm events	Spring thru Fall
Debris removal	Min.once per year & after major storm events	Spring thru Fall
Sediment removal	Min.once per year or when sediment is > 3" in stone-lined swale/ sediment forebay; Ensure sediment does not cause blockage of flume inlet	April
LANDSCAPE MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Mowing	Not required	Not required
Watering	Drought conditions only	July- August
Overseeding	As required	Early Spring or Fall preferred
Fertilizing	Not required	Not required
BASIN BED MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Aeration/Tilling	As needed	If standing water does not drain after 48 hours
Soil Replacement	As needed	If standing water does not drain after tilling (see above)
Snow Removal	Not required	Not required

- Loam and reseed with the originally specified seed mix. The basins and depressions are intended to be part of the landscape and vegetated practices. Mowing is not recommended.
- Cut back and thin vegetation annually. The seed mix specified is a low mow seed mix and the grass should be allowed to grow to depths of 12" to maintain a meadow appearance.
- Fertilizing: NOT REQUIRED. The grass seed selection should eliminate the need for fertilizers and pesticides.
- Watering: Watering is necessary during the initial grass establishment period (30 days min.), and during extreme drought conditions.

SUBSURFACE CHAMBERS

- Additional text to be added here in future versions

RECHARGE BASIN

- Additional text to be added here in future versions

FILTERING PRACTICE

BIORETENTION & BIOSWALES

- Removal of any trash and/or debris.
- Correction of any side slope erosion gullying, animal burrowing or slope slumping, and replanting as necessary.
- If standing water is observed in the bioretention 48 hours after a storm event, the top 6 inches of the bioretention soil/mulch area shall be rototilled or cultivated to breakup any hard-packed sediment, and replenished with mulch and replanted. The underdrain system shall be snaked and/or flushed. Replant with species as shown on Construction Plans.
- In a worst-case scenario, the entire filter bed may need to be re-installed. Upon failure, excavate bioretention soil, rake the pea gravel to loosen, inspect underdrain trench to determine if it has been compromised, repair as necessary, replace soil, replant, and mulch.

Plant maintenance is critical to the function of the bioretention area and should include the following:

- Cut back grasses, sedges, and rushes annually in the spring.
- Remove and replace vegetation as necessary, using the appropriate species as shown the Construction Plans. If at least 50 percent vegetation coverage is not established after two years, a reinforcement planting should be performed. When replacing a plant, place the new plant in the same location as the old plant, or as near as possible to the old location. The exception to this recommendation is if plant mortality is due to initial improper placement of the plant (i.e., in an area that is too wet or too dry) or if diseased/infected plant material was used and there is risk of persistence of the disease or fungus in the soil. The best time to plant is in early to mid-fall or early to mid-spring. Plants should be planted as soon as possible after purchase to ensure the best chance of survival. If possible, new plants should be approximately the same size as those that are being replaced. If surrounding plants have already become well established, care may need to be given to the new plants to ensure successful growth.
- Plant Thinning: Separation of herbaceous vegetation rootstock should occur when over-crowding is observed, or approximately once every 3 years.
- Mowing: Mowing of the bioretention area is NOT necessary or recommended. By design, plants in bioretention areas are meant to flourish throughout the growing season, leaving dry standing stalks during the dormant months. When mowing near bioretention areas, either use a mulching blade, or point the mower away from the bioretention area. Fresh grass clippings are high in nitrogen and should not be applied to bioretention areas, as they will compromise he facility's pollutant reduction effectiveness.
- Weeding: Weeding should be limited to invasive and exotic species, which can overwhelm the desired plant community. However, native non-invasive volunteer species are often desirable, as they add to the diversity of the plant community. Non-chemical methods (hand pulling and hoeing) are preferable; chemical herbicides should be avoided.
- Fertilizing: Proper selection of plant species and support during establishment of vegetation should eliminate the need for fertilizers and pesticides.
- Watering: Watering is necessary during the first few weeks after planting, and during

drought conditions. During drought conditions, plants should be watered a minimum of every seven to ten days.

- Mulching: Replace mulch every two years, in the early spring. The previous mulch layer should be removed, and properly disposed of, or roto-tilled into the soil surface. Mulch layers should not exceed 3" in depth. Avoid blocking inflow entrance points with mounded mulch or raised plantings. Once a full groundcover is established, mulching may

Bioretention & Bioswales Maintenance Schedule		
GENERAL MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Site Inspection	Min.once per year & after major storm events	Spring thru Fall
Debris removal	Min.once per year & after major storm events	Spring thru Fall
Sediment removal	Min.once per year or when sediment is > 3" in stone-lined swale/ sediment forebay; Ensure sediment does not cause blockage of flume inlet	April
LANDSCAPE MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Plant Cutting/Thinning	Annually	Early Spring
Weeding	As needed	April- October
Watering	Drought conditions only	July-August
Plant Replacement	As required	Spring or Fall preferred
Ferilizing	Should not be required	
MULCH MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Remove & replace existing mulch	Once every two years or as required	April
Re-mulch void areas	Min. 2x per year & after major storm events as needed	July & November
FILTER BED MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Tilling	As needed	if standing water does not drain after 48 hours
Soil Media Replacement	As needed	If standing water does not drain after tilling (see above)
Snow Removal	Not required	Not required

- not be necessary. All barren areas within the extents of the facility shall be replenished with mulch and re-vegetated to the original design standards.

SAND FILTER

General maintenance of the seeded sand filter falls under landscaping practices. A general inspection of the bioretention area shall be conducted annually and after storm events greater than or equal to the 1-year, 24-hour Type III precipitation event (2.7 in).

Maintenance work consists of the following:

- Materials deposited on the surface of the sand filter (e.g., trash and litter) should be removed manually on a quarterly basis.
- Correction of any side slope erosion gullying, animal burrowing or slope slumping, and replanting as necessary.
- If standing water is observed more than 48 hours after a storm event, then the following steps should be taken:
    - The underdrain system shall be snaked and/or flushed.

Sand Filter Maintenance Schedule		
GENERAL MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Site Inspection	Min.once per year & after major storm events	Spring thru Fall
Debris removal	Min.once per year & after major storm events	Spring thru Fall
Sediment removal	Min.once per year or when sediment is > 3" in stone-lined swale/sediment forebay; Ensure sediment does not cause blockage of flume inlet	April
LANDSCAPE MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Mowing	Min.twice per year or as necessary. Maintain 12" grass height	Spring thru Fall
Watering	Drought conditions only	July-August
Overseeding	As required	Spring or Fall preferred
Fertilizing	Not required	
FILTER BED MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Tilling	As needed	if standing water does not drain after 48 hours
Soil Media Replacement	As needed	If standing water does not drain after tilling (see above)
Snow Removal	Not required	Not required

- If the underdrain is not determined to not be clogged, the top 6 inches of sand should be removed and replaced with new materials. If discolored or contaminated material is found below this removed surface, then that material should also be removed and replaced until all contaminated sand has been removed from the filter chamber. The sand should be disposed of in accordance with all applicable federal and local regulations.

- Loam and reseed with the specified seed mix as shown on the Landscape Plan sheets of the Construction Plans as necessary.
- All structural components, which include the outlet structure, pipes, frame and grate, underdrain system, and timber check dams, should be inspected and any deficiencies should be reported.
- Mowing: The seed mix specified for the sand filter is a low mow seed mix and the grass should be allowed to grow to depths of 12" to maintain a meadow appearance. Mowing shall occur 4 times per growing season. When mowing near either use a mulching blade, or remove clippings from the filter bed area. Fresh grass clippings are high in nitrogen and should not be left in the filter bed as they will compromise he facility's pollutant reduction effectiveness or cause outlet structure clogging.
- Fertilizing: Proper grass seed selection during establishment of vegetation should eliminate the need for fertilizers and pesticides.
- Watering: Watering is necessary during the first grass establishment period 30 days min., and during drought conditions.

PRETREATMENT PRACTICES

GRASS CHANNEL AND FILTER STRIPS

Grass Channels and Filter Strips should be inspected on an annual basis and after storms of greater than or equal to the 1-year, 24-hour Type III precipitation event. Both the structural and vegetative components should be inspected and repaired. Maintenance work consists of the following:

- Trash and debris should be removed and properly disposed.
- When sediment accumulates to a depth of approximately 3 inches, it should be removed, and the swale should be reconfigured to its original dimensions.
- The vegetation in the dry swale should be mowed as required to maintain heights in the 4-6-inch range, with mandatory mowing once heights exceed 10 inches.
- If the surface of the dry swale becomes clogged to the point that standing water is observed on the surface 48 hours after precipitation events, the bottom should be roto-tilled or cultivated to break up any hard-packed sediment, and then reseeded.
    - Mowing: When mowing uses a mulching blade, or remove clippings from the swale area. Fresh grass clippings are high in nitrogen. Do not leave in the swale area as they canl compromise he facility's pollutant reduction effectiveness or cause outlet structure clogging.

SEDIMENT FOREBAYS

The sediment forebay functions as pretreatment for the access drive runoff and prior to the infiltration basin. Conduct a general inspection of the forebay annually and after major storm events. Maintenance work consists of the following:

- Inlets at Sediment Forebays: Inspect annually and after major storm events to monitor for proper operation, collection of solids, litter and/or trash, and deterioration. Clean annually and inspect for sediment build-up at inlet, which may cause blockage and re-direction of flow away from the applicable facility. Remove accumulated sediment and dispose of properly.
- Removal of any trash and/or debris.
- Removal of sediment when buildup is greater than or equal to 3 inches. Remove sediment by hand to minimize damage to plants. Replace any plants damaged or removed during sediment removal with the same plant genus and species as originally specified. Dispose sediment off-site in a pre-approved location.
- Correct side slope erosion gullying, animal burrowing or slope slumping, and replant as necessary.
- Correct any settling of the swale between the sediment forebay and the infiltration basin treatment area. Ensure that weirs/check dams are level. Correct any erosion that has occurred around the edges of the weir.
- Remove and replace vegetation as necessary, using the appropriate species.

DEEP SUMP CATCH BASIN

- Cleanout 2x per year

OIL AND GRIT SEPARATOR

- Cleanout 2x per year

ENERGY DISSIPATION BASINS

- Additional text to be added here in future versions

COMPOST FILTER SOCKS

- Additional text to be added here in future versions

PROPRIETARY DEVICES

- Per manufacturer's recommendations

Dry Swale Maintenance Schedule		
GENERAL MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Site Inspection	Min.once per year & after major storm events	Spring thru Fall
Debris removal	Min.once per year & after major storm events	Spring thru Fall
Sediment removal	Min.once per year or when sediment is > 3" in stone-lined swale/ sediment forebay; Ensure sediment does not cause blockage of flume inlet	April
LANDSCAPE MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Mowing	Min.twice per year or as necessary. Maintain 4"-6" grass height	Spring thru Fall
Watering	Drought conditions only	July-August
Overseeding	As required	Spring or Fall preferred
Fertilizing	Not required	
FILTER BED MAINTENANCE		
TASK	**FREQUENCY**	**TIME OF YEAR**
Tilling	As needed	if standing water does not drain after 48 hours
Soil Media Replacement	As needed	If standing water does not drain after tilling (see above)
Snow Removal	Not required	Not required

Study Area Statistics

Route 6 Sagamore Bridge to Orleans Rotary Study Area Calculations
R.O.W.
2,146.07 Acres
190,389.25 Linear feet
36.06 Miles
IMPERVIOUS COVER
547.94 Acres
26% Impervious
WOODS/GRASS
1,598.12 Acres
WATER BODIES
7.68 Acres within R.O.W.
IMPAIRED WATER BODIES
5.07 Acres