Operation and Maintenance Plan

for

Subsurface Gravel Wetland BMP Retrofit for Control of Nitrogen in Stormwater: An EPA Green Infrastructure Demonstration and Outreach Project for Hyannis Inner Harbor and the City of Barnstable, MA

Intersection of South Street & Pleasant Street
Barnstable, MA

February 2016

Prepared For:
City of Barnstable
Department of Public Works (DPW)
382 Falmouth Road
Hyannis, MA 02601

Prepared By:
Comprehensive Environmental Inc.
225 Cedar Hill Street
Marlborough, MA 017552

Introduction

This Operation and Maintenance (O&M) Plan is prepared for the **Subsurface Gravel Wetland BMP Retrofit constructed for Control of Nitrogen in Stormwater as part of a USEPA Green Infrastructure Demonstration and Outreach Project for Hyannis Inner Harbor and the City of Barnstable, MA.** Final as-built plans for the project are dated January 2016. The Plan is broken into two main components:

1. A narrative that provides background information on the project and describes the BMP; and
2. Plan elements to be used in performing maintenance of the BMP, included in attachments as follows:

Plan Elements:

Attachment A:	Operations Plan
Attachment B:	Inspection and Maintenance Checklist
Attachment C:	Operation and Maintenance Plans

Background

The City of Barnstable partnered with the Environmental Protection Agency (EPA), WaterVision, LLC, and Comprehensive Environmental Inc. (CEI) for a Green Infrastructure (GI) Education and Outreach Project located near the Gateway Marina.

The Gateway Marina area is located near the southern coast of Barnstable within the Lewis Bay watershed and located on the Hyannis Inner Harbor. Both Lewis Bay and Hyannis Harbor have been listed on the state's 303(d) list for several water quality parameters, including high levels of nitrogen. In response, the Massachusetts Department of Environmental Protection (MassDEP) issued a final Total Maximum Daily Load (TMDL) for total nitrogen on March 3, 2015 with recommendations to address nitrogen in stormwater through the use of Best Management Practices (BMPs).

As outlined in the 2003 Massachusetts Estuaries Project Embayment Restoration and Guidance for Implementation Strategies, stormwater transports nutrients, pathogens and bacteria, metals, suspended solids, and other constituents into embayments via point sources (e.g., stormwater outfall pipes) and nonpoint sources (e.g., runoff from fertilizer). Nitrogen compounds are present in the stormwater and eventually discharge into embayments. Anthropogenic sources of nitrogen carried by stormwater include fertilizers (from agricultural, suburban, and urban areas), septic system leachate, farm animal and pet waste, and atmospheric deposition and precipitation of nitrogen compounds from power plants and automobiles. Human activities that attract a concentration of birds can also cause nitrogen loading via stormwater.

As noted in the Oyster Pond TMDL, "coastal communities, including Falmouth [Barnstable], rely on clean, productive, and aesthetically pleasing marine and estuarine waters for tourism, recreational swimming, fishing, and boating, as well as for commercial fin fishing and shellfishing. Failure to reduce and control N loadings will result in complete replacement of eelgrass by macro-algae, a higher frequency of extreme decreases in dissolved oxygen concentrations and fish kills, widespread occurrence of unpleasant odors and visible scum, and a

complete loss of benthic macroinvertebrates throughout most of the embayment. As a result of these environmental impacts, commercial and recreational uses of Oyster Pond Embayment System coastal waters will be greatly reduced, and could cease altogether[1]."

The Massachusetts Division of Marine Fisheries currently prohibits shellfishing within northern areas of the Hyannis Inner Harbor, and conditionally approves shellfishing within southern areas. Therefore, stormwater mitigation should be performed, including construction of structural BMPs to treat and remove nitrogen from contributing outfall pipes.

Goal

The goal of this project is to demonstrate the efficacy of an innovative subsurface gravel wetland stormwater best management practice (BMP) retrofit for the control of nitrogen and improve the water quality of the Hyannis Inner Harbor, Barnstable MA.

Site Location & Description

The site is located near the intersection of South Street and Pleasant Street, just east of the Cape Cod Maritime Museum. Soils consist of a mix of gravel, sand, silt, and peat, likely associated with historic filling of the area for development purposes. Groundwater depth is located approximately one foot below the native ground surface based on soil borings performed on-site.

Owner and Operator:

BMP Owner:	City of Barnstable
O&M Responsible Party:	City of Barnstable DPW
Source of Long Term O&M Funding:	Annual department budgets

BMP Description

Design and construction of a single stormwater BMP retrofit, consisting of a hybrid bioretention area and subsurface gravel wetland (hereafter, subsurface gravel wetland (SGW); BMP; BMP retrofit) was constructed at the above location. As noted by the UNH Stormwater Center, "the majority of nitrogen washoff in parking lots occurs with the first 0.3-inch of precipitation" (Gunderson et al., 2012). Therefore, the BMP was generally designed according to guidance provided in the Massachusetts Stormwater Manual and modeled using a combination of Autodesk Storm and Sanitary Analysis and University of New Hampshire Stormwater Center guidance to store and treat stormwater from up to a 0.3-inch rainfall event over the impervious area from the contributing 6.9 acre subwatershed (approx. 3.5 acres impervious cover consisting of roadways, driveways and rooftops) that discharges into the existing municipal separate storm sewer system (MS4). MS4 stormwater flow merges to a 24-inch diameter clay pipe trunk line that runs down an easement and eventually discharges to Hyannis Inner Harbor.

A. BMP Inlet

To feed the BMP, a new deep sump Inlet Control Structure and Pretreatment Manhole (ISCPM), equipped with an oil/water separator was cut into the existing 24-inch clay pipe that runs down

[1]Final Oyster Pond Embayment System Total Maximum Daily Loads for Total Nitrogen (Report #96-TMDL-7 Control #245). Commonwealth of Massachusetts Executive Office of Energy and Environmental Affairs, Massachusetts Department of Environmental Protection, Bureau of Resource Protection. February 7, 2008.

an easement perpendicular to the site. This structure provides limited pretreatment by removing some sediment and other floatables prior to entering the BMP. A diversion wall was also constructed within this manhole to direct runoff from small stormwater events into the stormwater BMP while allowing storms exceeding BMP capacity to bypass through the existing drainage pipe into the harbor.

Upon commencement of a storm event, stormwater is collected in upstream catch basins, directed into the 24-inch clay pipe where it meets the diversion wall in the newly-installed ISCPM. The ISCPM then surcharges by approximately 2-feet, directing low flow events through the oil/water separator hood and into a 10-inch pipe. Diverted stormwater then flows to an Inlet Sampling Manhole (ISM) which is designed to monitor incoming flows and nitrogen concentrations, and finally into the BMP via a flared end section of pipe onto a riprap pad.

B. Bioretention Area of BMP

Once in the BMP, stormwater will pass through the bioretention portion of the treatment train. The bioretention area consists of 8-inches of a loam/compost mix (biosoil) planted with drought tolerant, native plantings as designed by the Cape Cod Commission (CCC). Plants uptake nitrogen through the root systems to provide partial stormwater treatment. This area also functions to oxidize sources of nitrogen, including total nitrogen, in preparation for treatment within the subsurface gravel wetland cell (described below). Side slopes varying from 2H:1V to 3H:1V are grassed and provide surface storage for up to the 0.3-inch storm event. Due to safety concerns, total stormwater depth will not exceed 2-feet.

The bioretention area is partially lined along the bottom with an impervious membrane, and thus stormwater is only allowed to infiltrate through the bioretention soils through an infiltration zone located towards the western end of the BMP. This infiltration zone consist of a permeable mix of gravel, sand, loam, and compost augmented with shredded newspaper[2] to promote and ensure oxidation of nitrogen sources prior to the subsurface gravel wetland cell. An additional perforated riser pipe is present to provide additional infiltration capacity (i.e., infiltration zone bypass) in the event that the infiltration zone gets clogged.

C. Subsurface Gravel Wetland Cell

Once stormwater passes through the infiltration zone or bypasses via the perforated riser pipe, it enters an underlying gravel storage reservoir (or, Internal Storage Reservoir (ISR)). This area consists of a 24-inch deep zone of crushed stone, lined on the sides and bottom of the BMP with an impervious liner to prevent infiltration into native soils and contact between stormwater and groundwater.[3] A 4-inch perimeter drain installed on the eastern side of the liner also helps to drain groundwater from the surrounding area. As stormwater flows east to west through the ISR and towards the BMP outlet, denitrification occurs. To date, information on the operation of gravel wetland cells indicates that some 24 to 33 hours of treatment time is required for complete

[2]In the bioretention area, the compost and newspaper provide a source of 'donor' electrons for microbially-assisted (aerobic) oxidation of nitrogen (ideally to nitrate (NO_3^{2-})), which is subsequently used in the subsurface gravel wetland cell as the source of electrons for microbially-assisted (anaerobic) reduction (i.e., denitrification) of nitrate to, ideally, nitrogen gas (N2).

[3]Because the ISR cell is essentially an anerobic bioreactor, it must be entirely self-contained and isolated from atmosphere to promote anoxic conditions favorable for denitrification.

denitrification. Typically however, the 0.3 inch storm will 'push out' the prior 0.3 inch storm volume held within the ISR. In this way, the BMP operates not unlike a plug flow reactor.

D. BMP Outlet

Once back at the western end (outlet) of the BMP, stormwater within the ISR drains into a 2-foot diameter high density polyethylene (HDPE) Outlet Control Structure. This structure has two 1-inch outlet orifices, with the first located at the top of the gravel reservoir and the second located approximately six-inches below. Orifices are sized to slowly release stormwater from the BMP over at least a 24-hour period while always maintaining a water level within the subsurface gravel layer. Again, the requisite retention time helps to maximize stormwater contact with anaerobic bacteria and thus provide maximum nitrogen removal. **It is important to understand that retention time of stormwater in the ISR – hence, BMP operation – is largely controlled by the sizing of the outlet orifice(s).** Although both the number and sizes of the orifices can be modified, these orifices have already been set for proper BMP operation. In addition, due to potential concerns regarding the presence and breeding of mosquitos, stormwater ponding that occurs after a storm is designed to drain down into the ISR in less than 48 hours.

Stormwater exiting the outlet orifices then flows through a 10-inch pipe into the Outlet Sampling Manhole (OSM) which is designed to monitor outlet flow and nitrogen concentrations, and then into a 4-foot diameter Overflow Structure, which is connected to the existing 24-inch clay pipe. This structure connects the BMP bypass pipe, 4-inch perimeter drain, and overflow from over the upstream diversion wall into the existing 24-inch clay pipe for outlet into the harbor. This structure is also equipped with a catch basin grate on the top which serves as an emergency overflow from the BMP.

Additional Recommendations

It is recommended that the Department of Public Works erect onsite signage regarding the following:

- Proper pet waste management to inform the public on the importance of minimizing pollutant sources to the environment; and
- Signage directing employees to mow side slopes only, not the basin bottom
- **CAUTION:** Not long after BMP construction was completed and before diversion wall stop logs were installed, a large storm was observed to have occurred over a very short duration (approximately 1-inch of rainfall within 1 hour). Because the sub-catchment is approximately 50% impervious cover, this resulted in abnormally high peak flow volume thru the MS4 trunk line with discharge to the BMP. It was further noted that grass clippings from the BMP area had become trapped, creating a partial blockage of the emergency Overflow Structure catch basin grate. It is important to emphasize that O&M personnel must anticipate similar BMP response in the future and **must maintain emergency BMP overflow capacity by ensuring the emergency Overflow Structure catch basin grate is unclogged, and that grass clippings from the BMP must be bagged and removed**. It may be advisable to remove diversion wall stop logs prior to very large storm events, which suggests routine real time monitoring of weather conditions.

Attachment A:
Operations Plan

Operations Plan

Project: Subsurface Gravel Wetland BMP Retrofit for Control of Nitrogen in Stormwater: An EPA Green Infrastructure Demonstration And Outreach Project for Hyannis Inner Harbor and the City of Barnstable, MA

Location: East of Cape Cod Maritime Museum, intersection of South Street and Pleasant Street

This BMP has been designed with several adjustable features to allow fine tuning of stormwater flow into and out of the BMP. Items and procedures are outlined in detail below.

CAUTION!

ALTERING ANY OF THE FOLLOWING CAN SEVERLY IMPACT THE FUNCTION OF THE BMP. IT IS HIGHLY RECOMMENDED THAT COMPREHENSIVE ENVIRONMENTAL, INC. BE CONTACTED AT 800-725-2550 PRIOR TO MAKING ALTERATIONS.

O&M Calibration

As construction, operation and maintenance of this BMP is part of a pilot program, the first year of operation (fall 2015 through summer 2016) will consist of some fine-tuning to optimize BMP functionality. Due to space constraints for this retrofit project, a typical sediment forebay could not be constructed. Instead, a deep-sump manhole (Inlet Control Structure and Pretreatment Manhole) was installed to provide some sediment removal prior to entering the BMP. As the system is designed to surcharge before entering the BMP, it is possible that sediment could accumulate in the deep sump manhole, potentially impacting stormwater flow capacity. The manhole should be inspected at least quarterly during the first year of operation to establish a benchmark for sediment removal. Additionally, the BMP should be periodically inspected after large storm events (>1") to ensure that it is draining in MORE THAN 24-hours but LESS THAN 48 hours. Should either condition occur, the Outlet Control Structure should be modified as outlined in the Outlet Control Structure section.

Inlet Control Structure and Pretreatment Manhole Diversion Wall

Description:

The Inlet Control Structure and Pretreatment Manhole (ICSPM) is equipped with a diversion wall to direct a portion of stormwater from the municipal separate storm sewer system (MS4) 24-inch diameter clay trunk line pipe either (a) into the BMP or (b) bypass the BMP and flow into the ocean. The center portion of the wall is constructed of stoplogs which may either be added or removed to increase or decrease stormwater flow into the BMP. The top of the wall is designed to be at elevation 6.60 (NAVD88 datum), or approximately 2.6-feet above the 24-inch inlet pipe invert. At this elevation, the BMP static ponding capacity will store the entire 0.3-inch storm event. At lower diversion wall elevations, storage will be decreased and bypass events will be more frequent.

Procedure in the Event of Excessive Winter Sand Accumulation:

It is expected that sediment accumulation will be highest during the winter and spring months due to winter sanding operations conducted on upstream roadways. Should sediment accumulation during these months exceed the maintenance abilities of the City, the stoplogs could be removed prior to winter sanding operations (approximately November) and reinstalled at the conclusion (approximately April).

Procedure in the Event of BMP Flooding:

Should the BMP flood* or otherwise fail to sufficiently pass large storm events, one or more stoplogs may be temporarily removed to allow for additional unrestricted flow. Stop logs should only be removed one at a time. For each stop log modification, evaluate BMP function during at least two future rain events before determining whether or not additional stoplogs must be removed. Removal of stoplogs is not a long-term fix for reoccurring problems since it reduces the efficiency of the BMP to remove stormwater pollutants. If a situation occurs that requires the long-term removal of stoplogs to prevent flooding or failure, contact CEI for BMP evaluation. In the event of a forecasted very large storm event (e.g. hurricane, 100-year event), it is recommended that the stoplogs be removed prior to the event to protect BMP integrity. Although designed to safely handle large storm events, very large events that overwhelm the upstream drainage system may cause undesired effects, particularly if accompanied by an oceanic storm surge event.

***Re: BMP Flooding:** As noted in the narrative above, not long after BMP construction was completed and before diversion wall stop logs were installed, a large storm occurred over a very short duration (approximately 1-inch of rainfall within 1 hour). Because the sub-catchment is approximately 50% impervious cover, this resulted in abnormally high peak flow volume through the MS4 trunk line, with discharge to the BMP. It was further noted that grass clippings from the BMP area had become trapped, creating a partial blockage of the emergency Overflow Structure catch basin grate. CAUTION: It is important to emphasize that O&M personnel must anticipate similar BMP response in the future and **must maintain emergency BMP overflow capacity by ensuring the emergency Overflow Structure catch basin grate is unclogged, and that grass clippings from the BMP area are bagged and removed**. It may be advisable to remove diversion wall stop logs prior to very large storm events, which suggests routine real time monitoring of weather conditions.

Maintenance Item	Effect	To Be Used When
a. Remove stoplogs	Reduces stormwater storage capacity of the BMP	• If excessive winter sand is accumulating during winter and spring months, impacting drainage system functionality. • If adverse effects such as flooding, surcharging, or insufficient flow. • If a very large storm event is forecasted (e.g. hurricane, 100-year event).
b. Replace stoplogs	Increases stormwater storage capacity of the BMP	• If previously removed prior to commencement of winter sanding. • If insufficient stormwater is remaining in the BMP. • At the conclusion of a very large storm event.

Effect:
Note that stormwater storage is key to nitrogen removal, and by removing stoplogs the storage capacity of the BMP will be reduced below the design storage volume. Stoplogs should only be removed if stormwater bypass capacity is insufficient during large storm events and causing issues such as flooding, system surcharging, erosion, etc.

Outlet Control Structure

Description:
The outlet control structure is currently equipped with two 1-inch diameter holes, with the first located at the top of the underground gravel cell and the second located approximately six inches lower. The combined orifices are designed to drain the aboveground portion within 24 to 48 hours.

Procedure in the Event the BMP is Draining in less than 24-hours:
Should the aboveground bioretention area drain too fast, one or more holes should be plugged to decrease outlet capacity. Note that holes should be small diameter (1-inch or less) and only be cored one at a time. Evaluate BMP function during at least three future rain events before determining whether or not additional hole(s) are needed.

Procedure in the Event the BMP is Not Draining within 48-hours:
Should the aboveground bioretention area drain too fast, one or more holes should be plugged to decrease outlet capacity. Note that holes should only be plugged one at a time. Evaluate BMP function during at least three future rain events before determining whether or not additional plug(s) are needed.

Maintenance Item	Effect	To Be Used When
a. Unplug existing hole	Reduces stormwater retention time of the BMP	• If BMP is taking more than 48-hours to drain dry.
b. Core new holes	Reduces stormwater retention time of the BMP	• If BMP is taking more than 48-hours to drain dry and the existing two 1-inch diameter holes provide insufficient flow when unplugged.
c. Plug holes	Increases stormwater retention time of the BMP	• If stormwater BMP is draining in less than 24-hours.

Effect:
Note that residence time is key to nitrogen removal, and the **BMP should not drain in LESS than 24-hours or MORE THAN 48-hours**. If this occurs, one or more holes will need to be plugged, unplugged, or cored until the BMP retains at least some water for the desired timeframe.

Attachment B:
Inspection and Maintenance Checklist

Maintenance Plan

Project: Subsurface Gravel Wetland BMP Retrofit for Control of Nitrogen in Stormwater: An EPA Green Infrastructure Demonstration And Outreach Project for Hyannis Inner Harbor and the City of Barnstable, MA

Location: East of Cape Cod Maritime Museum, intersection of South Street and Pleasant Street

Name of Person Conducting Inspection: _____ **Date of Inspection:** _____

Maintenance Item	Action	Frequency	Satisfactory/ Unsatisfactory	Comments
1. MS4 and Inlet Control Structure and Pretreatment Manhole (ICSPM)				
Structural condition	Visually inspect overflow riser for structural integrity. Repair or replace if necessary.	Inspect minimum of once a year.		
Inlet and outlet pipes	Ensure inlet and outlet pipes are clear of debris and free flowing.	Inspect spring & fall.		
Sediment accumulation	Check for excess sediment accumulation within the sump. Note depth in comments. Remove if necessary.	Inspect quarterly for the first year. Establish a schedule based on first year accumulation (min. 1x/yr).		
Debris and litter removal	Inspect for floatable debris or other materials behind the diversion wall. Remove if necessary.	Inspect spring & fall. Remove as needed.		
Diversion weir integrity	Inspect diversion weir for structural integrity and repair if necessary.	Inspect spring and fall.		
Stoplog removal (if needed, see Operations Plan)	Remove stoplogs at the end of the fall season to allow unrestricted water passage during freezing months.	Once in fall (if required, see Operations Plan).		
Stoplog replacement (if needed, see Operations Plan)	Reinsert stoplogs at the conclusion of freezing weather, typically at the start of spring.	Once in spring (if required, see Operations Plan).		
Oil-water separator hood	Verify that the oil/water separator hood is in place. Repair or replace if necessary.	Inspect spring and fall. Repair or replaced as needed.		

Maintenance Plan

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Location: East of Cape Cod Maritime Museum, intersection of South Street and Pleasant Street

Maintenance Item	Action	Frequency	Satisfactory/ Unsatisfactory	Comments
1. MS4 and Inlet Control Structure and Pretreatment Manhole (ICSPM)				
Upgradient catch basins	Inspect catch basins upgradient of BMP for sediment accumulation. Remove sediment from catch basins as required.	Inspect spring after winter sanding operations, and fall. Remove sediment as needed.		
2. Surface Bioretention Area				
Sediment accumulation	Visually inspect bioretention area to ensure that there is no sediment build-up.	Inspect quarterly. Establish a schedule based on first year accumulation (min. 1x/yr). Do not let sediment build up to 12 inches at any spot or completely cover vegetation.		
Debris & litter removal	Inspect for the presence of floatable debris or other materials within the surface BMP. Remove if necessary.	Inspect spring and fall. Remove as needed.		
Standing water	Verify that standing water is not present for more than 48 hours.	Twice a year, 48 hours after a storm.		
Erosion	Inspect area to ensure that there is no erosion, channelization or scouring, particularly near high velocity areas. Regrade as needed.	Inspect spring and fall. Regrade as needed.		
Flared end & riprap pad	Inspect flared end section and riprap pad to ensure stone is not displaced or filled with sediment. Remove sediment as necessary.	Inspect spring and fall. Repair or maintain as needed.		
Animal burrows	Inspect side slopes and surrounding area for animal burrows, holes, or other damage.	Inspect spring and fall, or more frequently if persistent damage is found. Repair or maintain as needed.		

Maintenance Plan

Project: Subsurface Gravel Wetland BMP Retrofit for Control of Nitrogen in Stormwater: An EPA Green Infrastructure Demonstration And Outreach Project for Hyannis Inner Harbor and the City of Barnstable, MA

Location: East of Cape Cod Maritime Museum, intersection of South Street and Pleasant Street

Maintenance Item	Action	Frequency	Satisfactory/ Unsatisfactory	Comments
3. Subsurface Gravel Wetland Cell (ISR)				
Inlet stand pipe	Check vertical standpipe for leaves and debris to ensure that the system is not obstructed.	Spring and fall.		
Outlet control structure	Inspect outlet control structure and verify that 1" orifice(s) are free flowing.	Spring and fall.		
Proper function of wetland	Visually inspect the infiltration area just in front of the vertical standpipe. Ensure that it is adequately draining water and is not filled with sediment.	Twice a year, 72 hours after a storm.		
4. Overflow Structure				
Structural condition	Visually inspect overflow riser for structural integrity (cracking, signs of collapse, etc.) Repair or replace if necessary.	Minimum once a year.		
Inlet & outlet pipes	Ensure inlet & outlet pipes are clear of debris & free flowing.	Inspect spring and fall. Remove as needed.		
Overflow grate clear of debris	Ensure overflow grate is clear of debris and is functioning properly.	Inspect spring and fall. Remove as needed.		
Tide/flap gate	Ensure flap gate on the BMP outlet pipe is present and functioning. Repair or replace if necessary.	Minimum once a year.		
Perimeter drain	Ensure perimeter drain inlet orifice is clear of debris and free flowing.	Inspect spring and fall. Remove as needed.		
5. Vegetation and Plantings				
Vegetation cover adequate	Inspect bioretention side slopes for adequate vegetation coverage. Re-seed and water bare areas as necessary.	Minimum once a year.		

Maintenance Plan

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Location: East of Cape Cod Maritime Museum, intersection of South Street and Pleasant Street

Maintenance Item	Action	Frequency	Satisfactory/ Unsatisfactory	Comments
5. Vegetation and Plantings (continued)				
Mow side slopes ONLY	Mow grassed side slopes. DO NOT mow plantings on bottom or around structures!	Biweekly between May and September.		
Vegetation suitably watered	Inspect vegetation health during dry conditions, particularly new plantings. Water thoroughly on a daily basis until health is reestablished.	Inspect during dry conditions (>7 days of no rain).		
Remove excess vegetation	Inspect for grass clippings and dead vegetation and remove.	Inspect monthly during growing season. Remove as needed.		
Invasive species absent	Inspect for invasive species encroachment. Remove if necessary.	Inspect monthly during growing season. Remove as needed.		
Weeds absent	Inspect for weed growth in the basin & around plants. Remove as required, at least twice per year.	Inspect monthly during growing season. Remove as needed (minimum twice/year).		
No evidence of insect infestation	Visually inspect for insect infestation. Treat with environmentally friendly pesticides.	Inspect monthly during growing season. Treat as needed.		

Additional Comments:

Action(s) to be Taken (Complete a Maintenance Record Form when any maintenance is performed):

Maintenance Plan

Project: Subsurface Gravel Wetland BMP Retrofit for Control of Nitrogen in Stormwater: An EPA Green Infrastructure Demonstration And Outreach Project for Hyannis Inner Harbor and the City of Barnstable, MA

Location: East of Cape Cod Maritime Museum, intersection of South Street and Pleasant Street

Maintenance Record

<table>
<tr><td>Date(s) of Maintenance:</td><td>Maintained By:</td></tr>
<tr><td>Date of Previous Maintenance:</td><td>Material Hauled Away By:</td></tr>
<tr><td rowspan="4">Maintenance Item & Type of Maintenance*:</td><td>Material Sent To:</td></tr>
<tr><td>Depth of Material Removed:</td></tr>
<tr><td>Volume of Material Removed:</td></tr>
<tr><td>Material Description:</td></tr>
<tr><td colspan="2">Comments:</td></tr>
</table>

*Types of Maintenance: 1) Debris & Litter Removal 2) Sediment Removal 3) Structural Integrity / Repairs

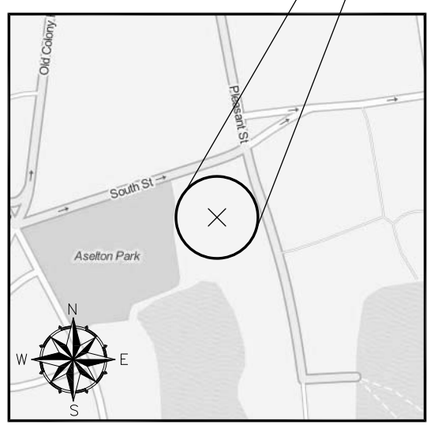
Attachment C:
Operation and Maintenance Plans

EPA Green Infrastructure
Stormwater BMP Retrofit for Two Cape Cod Municipalities
A Demonstration and Outreach Project

BARNSTABLE, MA
NOVEMBER 2015 - CONSTRUCTION AS-BUILTS

BARNSTABLE, MA
Gateway Marina BMP - Gravel Bioretention
Cell, South Street & Pleasant Street

SHEET	TITLE
C-1	EXISTING CONDITIONS
C-2	PROPOSED CONDITIONS
C-3	UTILITY PLAN
C-4	LANDSCAPING AND SURFACE TREATMENTS
C-5	DETAILS
C-6	DETAILS



BARNSTABLE PROJECT
SCALE: 1" = 200'

EPA United States Environmental Protection Agency, Region 1
5 POST OFFICE SQUARE, SUITE 100
BOSTON, MA 02109

WaterVision, LLC
481 GREAT ROAD, SUITE 3
ACTON, MA 01720

COMPREHENSIVE ENVIRONMENTAL INCORPORATED
21 DEPOT STREET
MERRIMACK, NH 03054

GATEWAY MARINA BMP, BARNSTABLE – EXISTING CONDITIONS

General Notes

1. THE LOCATION OF UNDERGROUND UTILITIES HAVE NOT BEEN VERIFIED OR INSPECTED. THE CONTRACTOR, PRIOR TO COMMENCEMENT OF CONSTRUCTION, SHALL VERIFY THE LOCATION OF ALL UTILITIES AND CONTACT "DIG–SAFE" AT 1–888–344–7233.

2. THE CONTRACTOR SHALL EXERCISE EXTREME CAUTION TO PREVENT ANY DAMAGE TO ADJACENT PROPERTIES. ALL AREAS WHICH ARE AFFECTED BY THE CONTRACTOR'S OPERATIONS SHALL BE RETURNED TO THEIR ORIGINAL CONDITION OR BETTER, AT NO ADDITIONAL COST TO THE OWNER.

3. ANY CHANGE IN FIELD CONDITIONS SHALL BE REPORTED TO THE ENGINEER TO INSURE THAT ANY MODIFICATIONS TO THE ORIGINAL DESIGN ARE PROPER AND ADEQUATE TO SERVE THE PROJECT'S NEEDS AND COMPLY WITH THE APPLICABLE STANDARDS AND REGULATIONS.

4. CONTRACTOR SHALL IMMEDIATELY REPAIR OR FILL ANY POTHOLES THAT OCCUR DUE TO CONSTRUCTION.

5. CONTRACTOR SHALL REPAIR ALL PAVING OR BRICKWORK ON SITE DAMAGED OR REMOVED DURING CONSTRUCTION.

6. REMOVE ALL TEMPORARY EROSION CONTROLS FROM THE SITE AT THE CONCLUSION OF CONSTRUCTION ACTIVITIES.

7. STORMWATER SHALL NOT BE DIRECTED INTO THE BASIN UNTIL ALL PLANTINGS ARE SUITABLY ESTABLISHED. CONTRACTOR SHALL EITHER TIE INTO THE EXISTING CATCH BASIN LAST OR INSTALL A REMOVAL PLUG.

N
W E
S

LEGEND

LINE STYLE	DESCRIPTION
	EXISTING 1' CONTOUR
	EXISTING 5' CONTOUR
W	EXISTING UNDERGROUND WATER
S	EXISTING UNDERGROUND SEWER
G	EXISTING UNDERGROUND GAS
T	EXISTING TELEPHONE LINES
OHW	EXISTING OVERHEAD WIRES
D	EXISTING DRAINAGE
x	EXISTING FENCE
P/L	PROPERTY LINES
HWM	BORDERING VEGETATED WETLANDS
50'	50' BVW BUFFER ZONE
100'	100' BVW BUFFER ZONE
	FLOOD ZONE AE

0 20 40 60
SCALE: 1"=20'

No.	Revision/Issue	Date
5	As–Builts	11/15
4	100% Design for Const.	04/15
3	90% Design	03/15
2	60% Design	02/15
1	Conceptual	01/15

WaterVision, LLC
481 GREAT ROAD, SUITE 3
ACTON, MA 01720

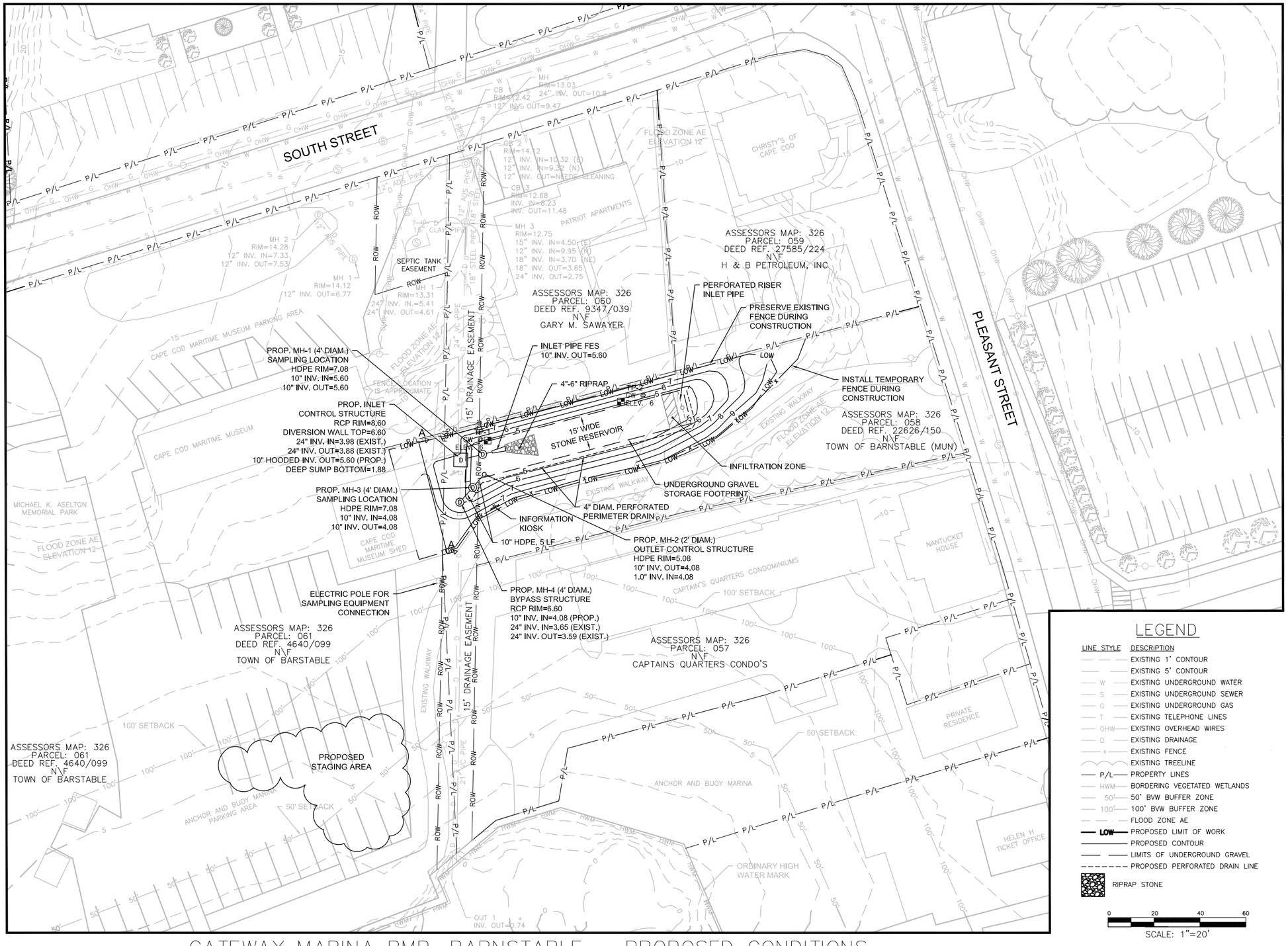
COMPREHENSIVE ENVIRONMENTAL INCORPORATED
21 DEPOT STREET
MERRIMACK, NH 03054

EPA Green Infrastructure Education and Outreach Project

GATEWAY MARINA BMP, GRAVEL BIORETENTION CELL

South Street and Pleasant Street, Barnstable MA

Project No.: 677–2	Sheet
Date: NOVEMBER 2015	C–1
Drawn By: NC	
Checked By: ML	
Horizontal Datum: NAD88	
Vertical Datum: NAVD88	



LEGEND

LINE STYLE	DESCRIPTION
	EXISTING 1' CONTOUR
	EXISTING 5' CONTOUR
W	EXISTING UNDERGROUND WATER
S	EXISTING UNDERGROUND SEWER
G	EXISTING UNDERGROUND GAS
T	EXISTING TELEPHONE LINES
OHW	EXISTING OVERHEAD WIRES
D	EXISTING DRAINAGE
x	EXISTING FENCE
	EXISTING TREELINE
P/L	PROPERTY LINES
HWM	BORDERING VEGETATED WETLANDS
50'	50' BVW BUFFER ZONE
100'	100' BVW BUFFER ZONE
	FLOOD ZONE AE
LOW	PROPOSED LIMIT OF WORK
	PROPOSED CONTOUR
	LIMITS OF UNDERGROUND GRAVEL
	PROPOSED PERFORATED DRAIN LINE
	RIPRAP STONE

0 20 40 60

SCALE: 1"=20'

GATEWAY MARINA BMP, BARNSTABLE – PROPOSED CONDITIONS

General Notes

1. THE LOCATION OF UNDERGROUND UTILITIES HAVE NOT BEEN VERIFIED OR INSPECTED. THE CONTRACTOR, PRIOR TO COMMENCEMENT OF CONSTRUCTION, SHALL VERIFY THE LOCATION OF ALL UTILITIES AND CONTACT "DIG–SAFE" AT 1–888–344–7233.

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3. ANY CHANGE IN FIELD CONDITIONS SHALL BE REPORTED TO THE ENGINEER TO INSURE THAT ANY MODIFICATIONS TO THE ORIGINAL DESIGN ARE PROPER AND ADEQUATE TO SERVE THE PROJECT'S NEEDS AND COMPLY WITH THE APPLICABLE STANDARDS AND REGULATIONS.

4. CONTRACTOR SHALL IMMEDIATELY REPAIR OR FILL ANY POTHOLES THAT OCCUR DUE TO CONSTRUCTION.

5. CONTRACTOR SHALL REPAIR ALL PAVING OR BRICKWORK ON SITE DAMAGED OR REMOVED DURING CONSTRUCTION.

6. REMOVE ALL TEMPORARY EROSION CONTROLS FROM THE SITE AT THE CONCLUSION OF CONSTRUCTION ACTIVITIES.

7. STORMWATER SHALL NOT BE DIRECTED INTO THE BASIN UNTIL ALL PLANTINGS ARE SUITABLY ESTABLISHED. CONTRACTOR SHALL EITHER TIE INTO THE EXISTING CATCH BASIN LAST OR INSTALL A REMOVAL PLUG.

N W E S

No.	Revision/Issue	Date
5	As–Builts	11/15
4	100% Design for Const.	04/15
3	90% Design	03/15
2	60% Design	02/15
1	Conceptual	01/15

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21 DEPOT STREET
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EPA Green Infrastructure Education and Outreach Project

GATEWAY MARINA BMP, GRAVEL BIORETENTION CELL

South Street and Pleasant Street, Barnstable MA

Project No.: 677–2	Sheet
Date: NOVEMBER 2015	C–2
Drawn By: NC	
Checked By: ML	
Horizontal Datum: NAD88	
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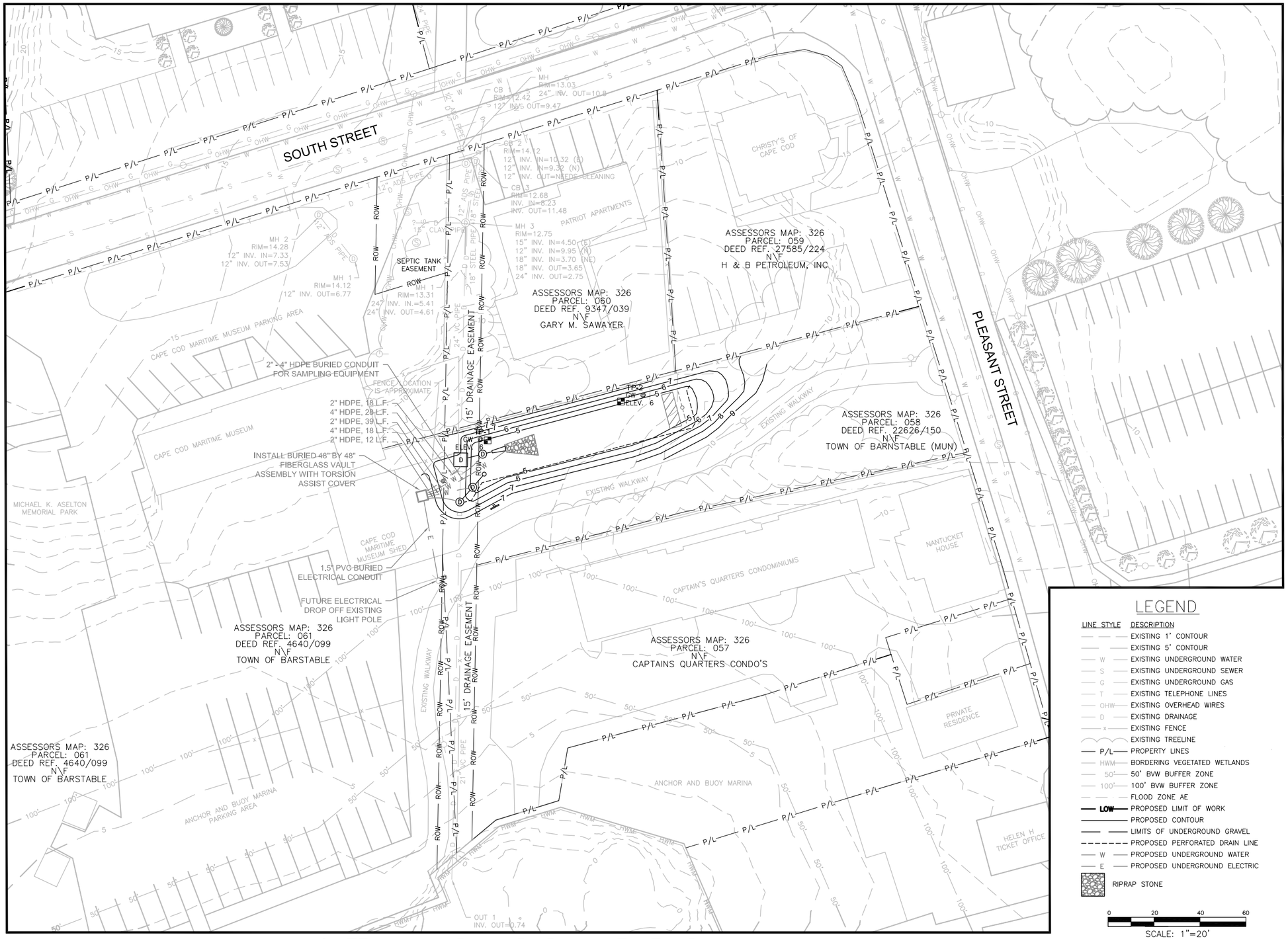

GATEWAY MARINA BMP – UTILITY PLAN

LEGEND

LINE STYLE	DESCRIPTION
	EXISTING 1' CONTOUR
	EXISTING 5' CONTOUR
W	EXISTING UNDERGROUND WATER
S	EXISTING UNDERGROUND SEWER
G	EXISTING UNDERGROUND GAS
T	EXISTING TELEPHONE LINES
OHW	EXISTING OVERHEAD WIRES
D	EXISTING DRAINAGE
x	EXISTING FENCE
	EXISTING TREELINE
P/L	PROPERTY LINES
HWM	BORDERING VEGETATED WETLANDS
50'	50' BVW BUFFER ZONE
100'	100' BVW BUFFER ZONE
	FLOOD ZONE AE
LOW	PROPOSED LIMIT OF WORK
	PROPOSED CONTOUR
	LIMITS OF UNDERGROUND GRAVEL
	PROPOSED PERFORATED DRAIN LINE
W	PROPOSED UNDERGROUND WATER
E	PROPOSED UNDERGROUND ELECTRIC
	RIPRAP STONE

0 20 40 60

SCALE: 1"=20'

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N W E S

No.	Revision/Issue	Date
6	As–Builts	11/15
5	Utility Layout	09/15
4	100% Design for Const.	04/15
3	90% Design	03/15
2	60% Design	02/15
1	Conceptual	01/15

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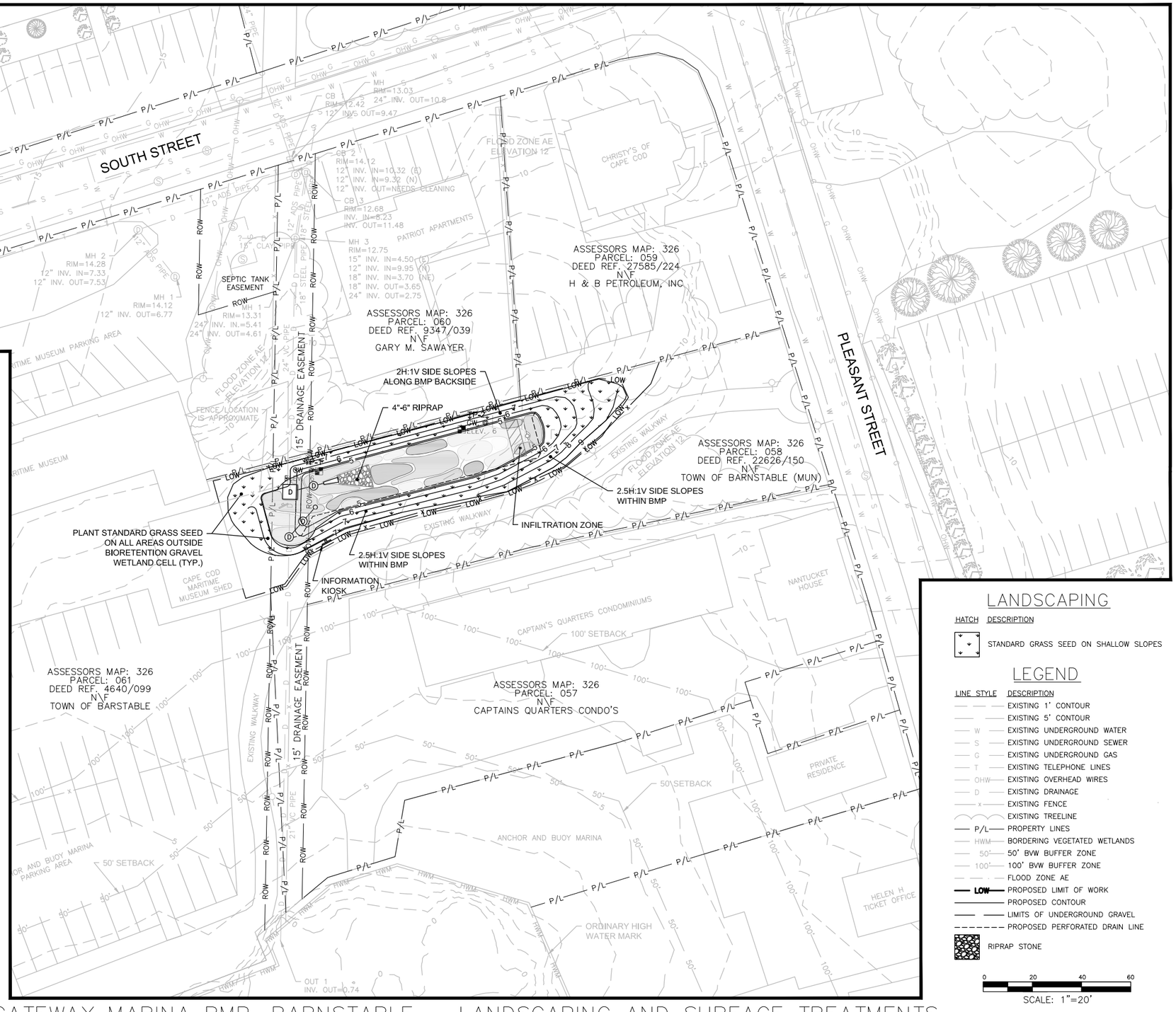
Sheet C–3

PLANTING SCHEDULE

KEY	QUANTITY	NAME
	50	TUSSOCK SEDGE *(Carex stricta)*
	75	COMMON RUSH *(Juncus effusus)*
	350	SWITCHGRASS *(Panicum virqatum)*
	15	BLUE FLAB *(Iris versicolor)*
	50	JOE PYE WEED *(Eupatorium maculatum)*
	20	BLUE CARDINAL FLOWER *(Lobelia siphilitica)*
	100	FOX SEDGE *(Carex Vulpinoidea)*
	15	NEW YORK ASTER *(Aster novi-belgii)*
	20	NEW YORK ASTER *(Aster novi-belgii)*
	40	BLUE CARDINAL FLOWER *(Lobelia siphilitica)*
	50	NEW YORK IRONWEED *(Vernonia noveboracensis)*
	50	NEW ENGLAND ASTER *(Aster novae-angliae)*
	150	BITTER PANICGRASS *(Panicum amarum)*
	40	BLUE CARDINAL FLOWER *(Lobelia siphilitica)*
	35	BLUE FLAB *(Iris versicolor)*
	75	COMMON RUSH *(Juncus effusus)*
	50	NEW YORK IRONWEED *(Vernonia noveboracensis)*
	15	NEW YORK ASTER *(Aster novi-belgii)*
	15	SWITCHGRASS *(Panicum virqatum)*
	20	BLUE CARDINAL FLOWER *(Lobelia siphilitica)*
	50	TUSSOCK SEDGE *(Carex stricta)*
	20	BLUE CARDINAL FLOWER *(Lobelia siphilitica)*



LANDSCAPING

HATCH	DESCRIPTION
	STANDARD GRASS SEED ON SHALLOW SLOPES

LEGEND

LINE STYLE	DESCRIPTION
	EXISTING 1' CONTOUR
	EXISTING 5' CONTOUR
W	EXISTING UNDERGROUND WATER
S	EXISTING UNDERGROUND SEWER
G	EXISTING UNDERGROUND GAS
T	EXISTING TELEPHONE LINES
OHW	EXISTING OVERHEAD WIRES
D	EXISTING DRAINAGE
x	EXISTING FENCE
	EXISTING TREELINE
P/L	PROPERTY LINES
HWM	BORDERING VEGETATED WETLANDS
50'	50' BVW BUFFER ZONE
100'	100' BVW BUFFER ZONE
	FLOOD ZONE AE
LOW	PROPOSED LIMIT OF WORK
	PROPOSED CONTOUR
	LIMITS OF UNDERGROUND GRAVEL
	PROPOSED PERFORATED DRAIN LINE
	RIPRAP STONE

0 20 40 60

SCALE: 1"=20'

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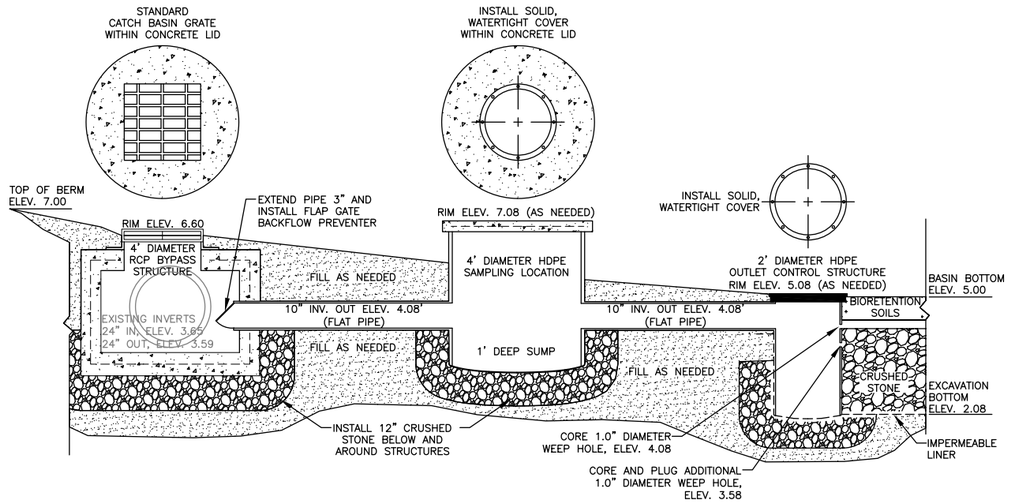
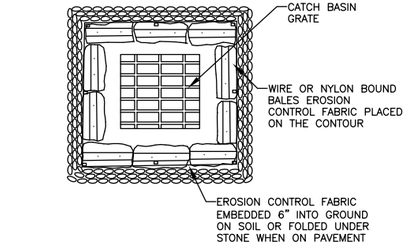
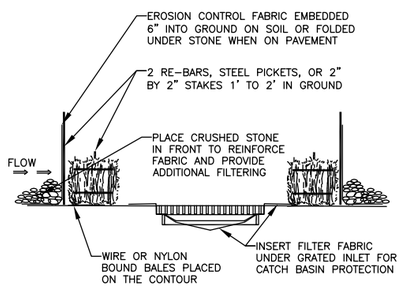
GATEWAY MARINA BMP, BARNSTABLE - LANDSCAPING AND SURFACE TREATMENTS



BMP OVERFLOW DETAILS



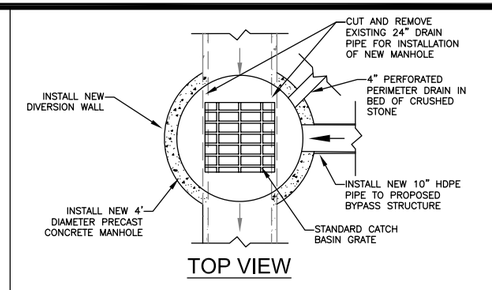
PLAN VIEW



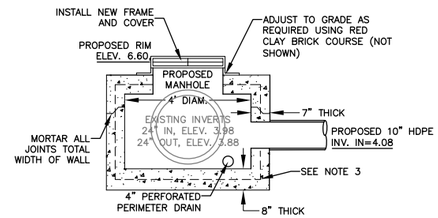
PROFILE VIEW

NOTES
1. SILT FENCE SHALL BE EMBEDDED IN THE SOIL A MINIMUM OF 6"
2. INSPECTION SHALL BE FREQUENT AND REPAIR OR REPLACEMENT SHALL BE MADE PROMPTLY AS NEEDED

CATCH BASIN EROSION CONTROL

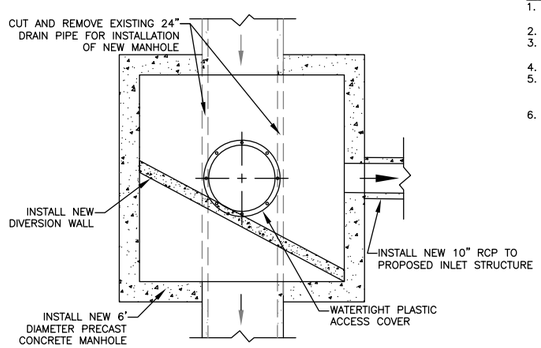


TOP VIEW



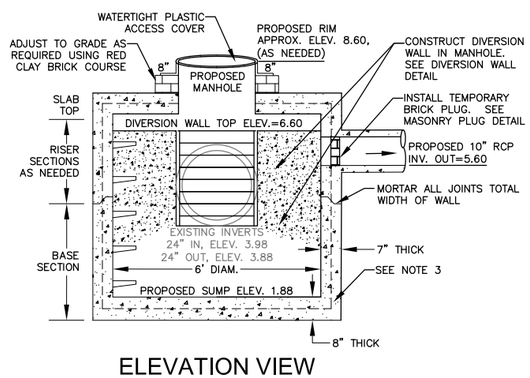
ELEVATION VIEW

RCP BYPASS STRUCTURE



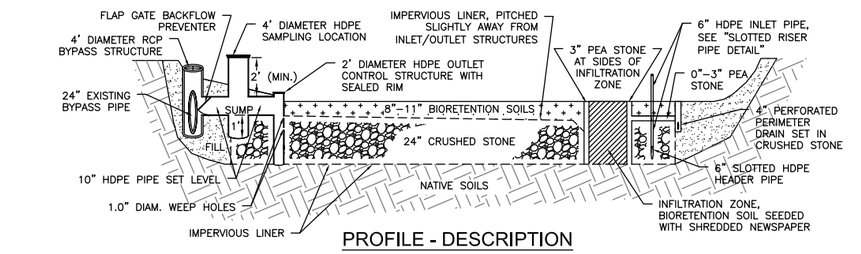
TOP VIEW

NOTES
1. MANHOLE SHALL BE IN ACCORDANCE WITH SECTION 702 OF THE MA STANDARD SPECIFICATIONS
2. CIRCUMFERENTIAL STEEL REINFORCEMENT REQUIRED = 0.15 SQ. IN./LF. MINIMUM
3. STEEL REINFORCEMENT FOR BASE SECTION BOTTOM SHALL BE A MINIMUM OF 0.12 SQ. IN./LF. (BOTH WAYS)
4. ONE POUR MONOLITHIC BASE SECTION.
5. ANY NECESSARY ADJUSTMENTS DURING CONSTRUCTION WILL BE DONE BY SAW-CUTTING AND/OR CORING ONLY. NO JACKHAMMERS, HAMMERS AND CHISELS OR PNEUMATIC TOOLS WILL BE ALLOWED
6. STEPS SHALL CONFORM TO STD. 5.3.0 AND SHALL BE INSTALLED AT THE CASTING PLANT



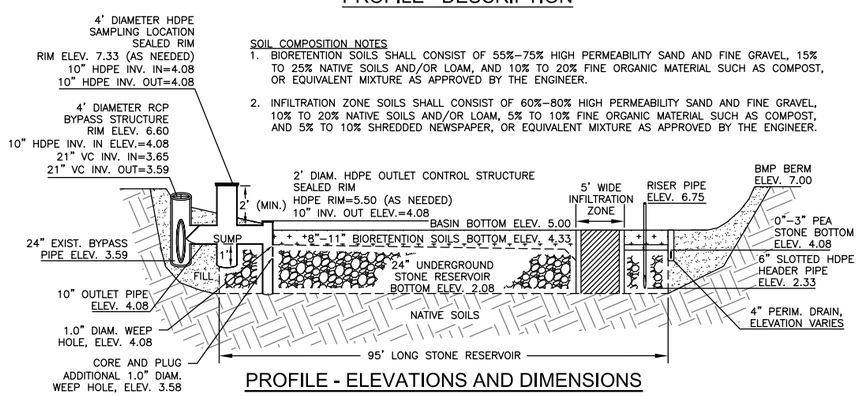
ELEVATION VIEW

RCP INLET CONTROL STRUCTURE



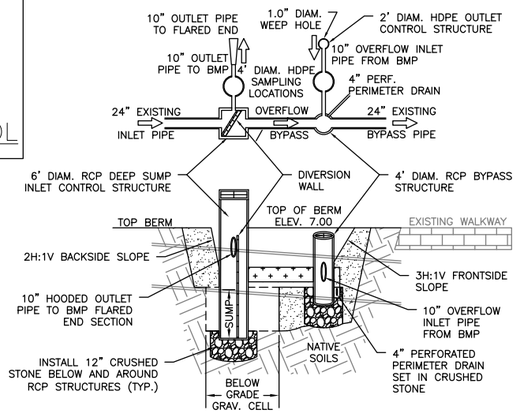
PROFILE - DESCRIPTION

SOIL COMPOSITION NOTES
1. BIORETENTION SOILS SHALL CONSIST OF 55%-75% HIGH PERMEABILITY SAND AND FINE GRAVEL, 15% TO 25% NATIVE SOILS AND/OR LOAM, AND 10% TO 20% FINE ORGANIC MATERIAL SUCH AS COMPOST, OR EQUIVALENT MIXTURE AS APPROVED BY THE ENGINEER.
2. INFILTRATION ZONE SOILS SHALL CONSIST OF 60%-80% HIGH PERMEABILITY SAND AND FINE GRAVEL, 10% TO 20% NATIVE SOILS AND/OR LOAM, 5% TO 10% FINE ORGANIC MATERIAL SUCH AS COMPOST, AND 5% TO 10% SHREDDED NEWSPAPER, OR EQUIVALENT MIXTURE AS APPROVED BY THE ENGINEER.

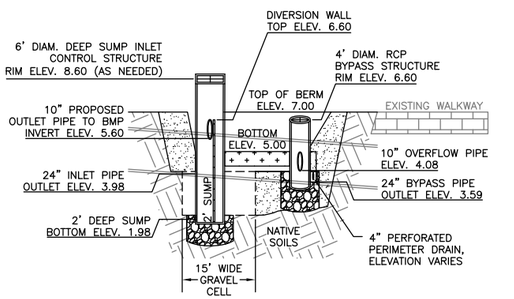


PROFILE - ELEVATIONS AND DIMENSIONS

STORMWATER BMP DETAILS



CROSS-SECTION A-A - DESCRIPTION



CROSS-SECTION A-A - ELEVATIONS AND DIMENSIONS

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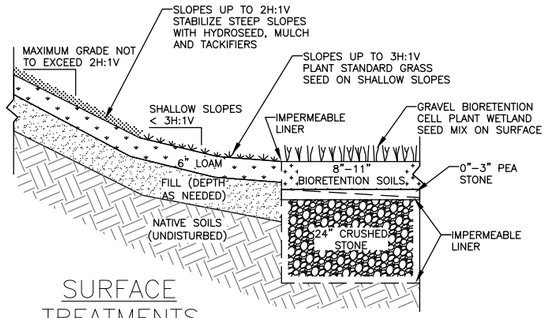
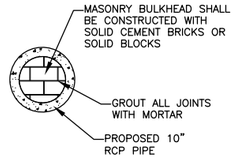
GATEWAY MARINA BMP, BARNSTABLE - DETAILS



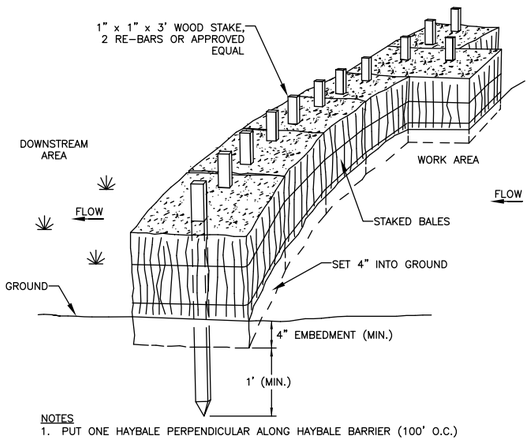
SURFACE TREATMENTS

SOIL COMPOSITION NOTES

1. BIORETENTION SOILS SHALL CONSIST OF 55%–75% HIGH PERMEABILITY SAND AND FINE GRAVEL, 15% TO 25% NATIVE SOILS AND/OR LOAM, AND 10% TO 20% FINE ORGANIC MATERIAL SUCH AS COMPOST, OR EQUIVALENT MIXTURE AS APPROVED BY THE ENGINEER.
2. INFILTRATION ZONE SOILS (NOT SHOWN) SHALL CONSIST OF 60%–80% HIGH PERMEABILITY SAND AND FINE GRAVEL, 10% TO 20% NATIVE SOILS AND/OR LOAM, 5% TO 10% FINE ORGANIC MATERIAL SUCH AS COMPOST, AND 5% TO 10% SHREDDED NEWSPAPER, OR EQUIVALENT MIXTURE AS APPROVED BY THE ENGINEER.



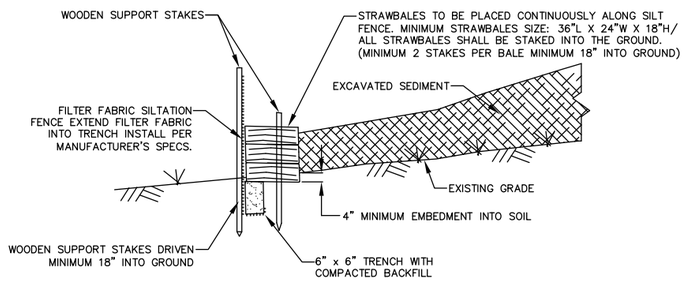
TEMPORARY PLUG



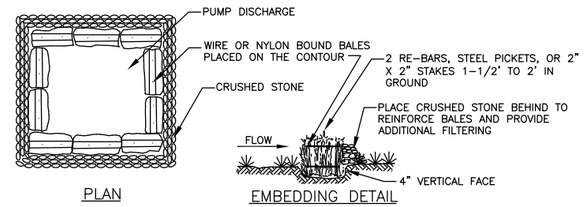
NOTES

1. PUT ONE HAYBALE PERPENDICULAR ALONG HAYBALE BARRIER (100' O.C.)

PERIMETER EROSION CONTROLS



MATERIAL DE–WATERING AREA

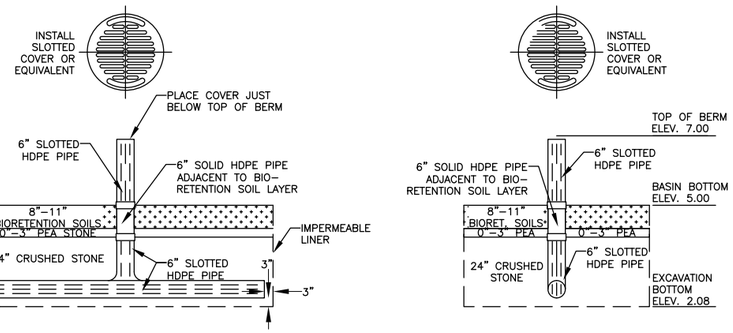


PLAN EMBEDDING DETAIL

STRAW BALE BARRIER CONSTRUCTION SPECIFICATIONS

1. BALES SHALL BE PLACED IN A ROW WITH ENDS TIGHTLY BUTTED.
2. EACH BALE SHALL BE EMBEDDED IN THE SOIL A MINIMUM OF 4".
3. BALES SHALL BE SECURELY ANCHORED IN PLACE BY STAKES OR RE–BARS DRIVEN THROUGH THE BALES. THE FIRST STAKE IN EACH BALE SHALL BE ANGLED TOWARD PREVIOUSLY LAID BALE TO FORCE BALES TOGETHER.
4. INSPECTION SHALL BE FREQUENT AND REPAIR OR REPLACEMENT SHALL BE MADE PROMPTLY AS NEEDED.

PUMPING DE–WATERING DISCHARGE AREA, HAY BALES

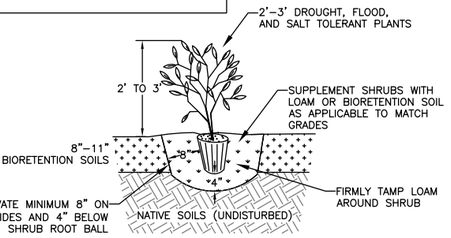


CROSS-SECTION VIEW ELEVATION VIEW

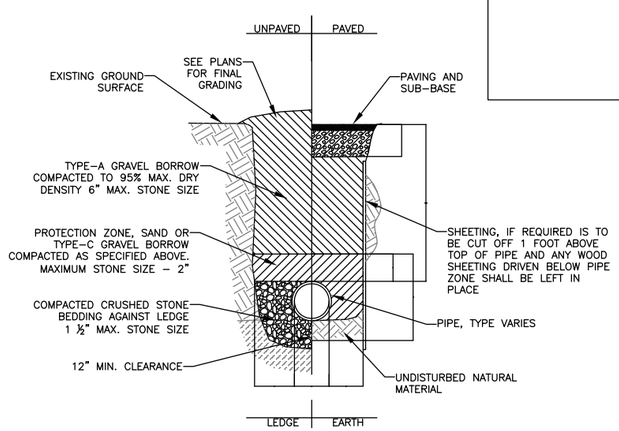
SLOTTED PIPE SPECIFICATIONS

1. SLOTS SHALL BE A MINIMUM OF 0.040 INCHES WIDE SPACED EVERY 0.25".

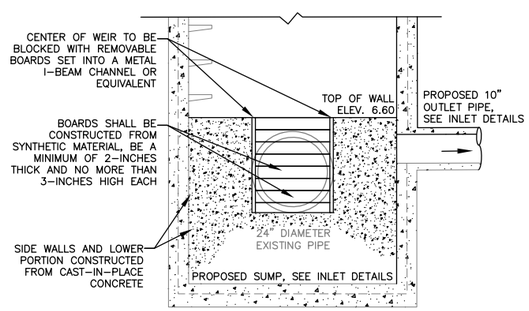
SLOTTED RISER PIPE DETAIL



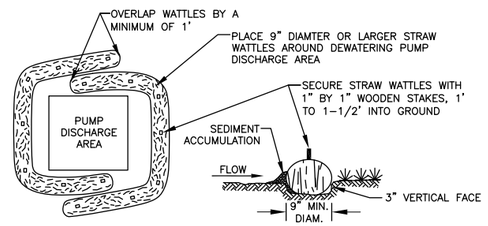
PLANTING DETAIL



PIPE TRENCHING DETAIL



DIVERSION WALL



PLAN EMBEDDING DETAIL

STRAW WATTLE DEWATERING AREA CONSTRUCTION SPECIFICATIONS

1. WATTLES SHALL BE PLACED IN A ROW WITH ENDS OVERLAPPING A MINIMUM OF 1'.
2. EACH WATTLE SHALL BE EMBEDDED IN THE SOIL A MINIMUM OF 3".
3. WATTLES SHALL BE SECURELY ANCHORED IN PLACE BY STAKES OR RE–BARS INSTALLED AT A MINIMUM EVERY 3' ON–CENTER.
4. INSPECTION SHALL BE FREQUENT AND REPAIR OR REPLACEMENT SHALL BE MADE PROMPTLY AS NEEDED.
5. SEDIMENT SHALL BE REMOVED WHEN THE HEIGHT REACHES THE HALFWAY POINT ON THE STRAW WATTLE.

PUMPING DE–WATERING DISCHARGE AREA, STRAW WATTLES

General Notes

1. THE LOCATION OF UNDERGROUND UTILITIES HAVE NOT BEEN VERIFIED OR INSPECTED. THE CONTRACTOR, PRIOR TO COMMENCEMENT OF CONSTRUCTION, SHALL VERIFY THE LOCATION OF ALL UTILITIES AND CONTACT "DIG–SAFE" AT 1–888–344–7233.
2. THE CONTRACTOR SHALL EXERCISE EXTREME CAUTION TO PREVENT ANY DAMAGE TO ADJACENT PROPERTIES. ALL AREAS WHICH ARE AFFECTED BY THE CONTRACTOR'S OPERATIONS SHALL BE RETURNED TO THEIR ORIGINAL CONDITION OR BETTER, AT NO ADDITIONAL COST TO THE OWNER.
3. ANY CHANGE IN FIELD CONDITIONS SHALL BE REPORTED TO THE ENGINEER TO INSURE THAT ANY MODIFICATIONS TO THE ORIGINAL DESIGN ARE PROPER AND ADEQUATE TO SERVE THE PROJECT'S NEEDS AND COMPLY WITH THE APPLICABLE STANDARDS AND REGULATIONS.
4. CONTRACTOR SHALL IMMEDIATELY REPAIR OR FILL ANY POTHOLES THAT OCCUR DUE TO CONSTRUCTION.
5. CONTRACTOR SHALL REPAIR ALL PAVING OR BRICKWORK ON SITE DAMAGED OR REMOVED DURING CONSTRUCTION.
6. REMOVE ALL TEMPORARY EROSION CONTROLS FROM THE SITE AT THE CONCLUSION OF CONSTRUCTION ACTIVITIES.
7. STORMWATER SHALL NOT BE DIRECTED INTO THE BASIN UNTIL ALL PLANTINGS ARE SUITABLY ESTABLISHED. CONTRACTOR SHALL EITHER TIE INTO THE EXISTING CATCH BASIN LAST OR INSTALL A REMOVAL PLUG.

No.	Revision/Issue	Date
5	As–Builts	11/15
4	100% Design for Const.	04/15
3	90% Design	03/15
2	60% Design	02/15
1	Conceptual	01/15

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EPA Green Infrastructure Education and Outreach Project

GATEWAY MARINA BMP, GRAVEL BIORETENTION CELL

South Street and Pleasant Street, Barnstable MA

Project No.: 677–2	Sheet
Date: NOVEMBER 2015	C–6
Drawn By: NC	
Checked By: ML	
Horizontal Datum: NAD88	
Vertical Datum: NAVD88	

GATEWAY MARINA BMP, BARNSTABLE – DETAILS