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Memorandum

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CC	Betsy Shreve, AICP, AECOM Project Director Paul Dombrowski, AECOM Mark Owen, AECOM Juli Marrion, AECOM James Begley, MT Environmental Restoration
Subject	**Town of Orleans, MA** **Water Quality and Wastewater Planning** **Task Number 3 – NT Demonstration Projects** **Deliverable 3.c.5 - Draft Technical Memorandum on Site Characterization and Evaluation for Permeable Reactive Barriers (evaluation criteria and ranking)**
Project Number	60476644
From	Thomas Parece, P.E., AECOM Project Manager
Date	January 15, 2016

1. Background

This Technical Memorandum documents the process used to select locations for Permeable Reactive Barrier (PRB) Demonstration Testing. An objective assessment of potential locations, including use of a system to record rankings of sites based on established criteria, formed the basis for selection. The selected locations will be used to develop a Preliminary Engineering Work Plan, which will detail designs, schedules, and costs for PRB demonstrations. Strategies for performance verification through groundwater monitoring will be included in the Work Plan.

a. Key Terms

(1) Permeable Reactive Barrier (PRB) – consists of a zone of reactive material installed in the path of a dissolved contaminant (e.g., nitrate) plume.

(2) Denitrification – biological conversion of nitrate to inert nitrogen gas by naturally occurring bacteria.

(3) Reactive media (amendments) – material used to stimulate bacteria to transform nitrate to nitrogen gas.

(4) PRB Installation Methods

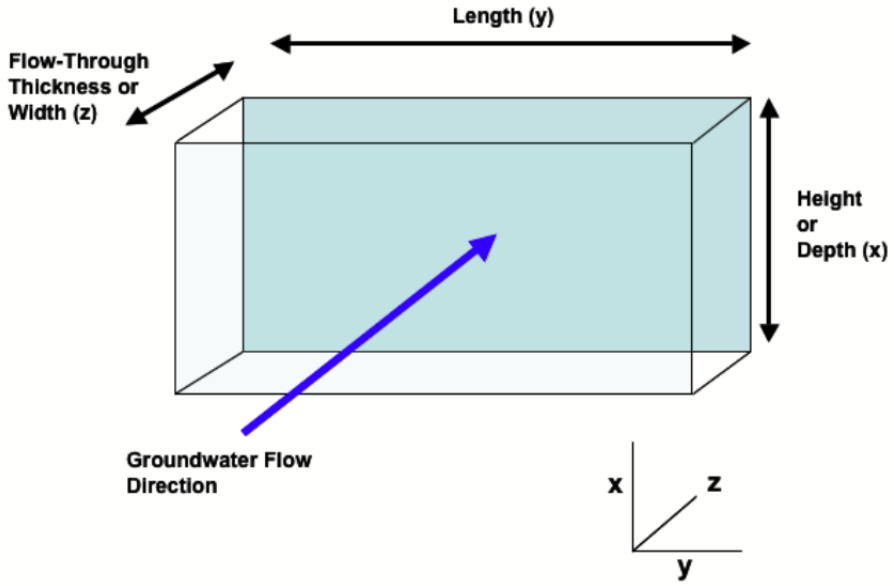
- excavating a long deep trench to place reactive solid material in the path of target groundwater,
- using soil boring and/or wells to inject a reactive liquid or emulsion in the path or target groundwater flow, and
- using soil borings and wells to place a solid reactive material in the path of target groundwater.

(5) Mass flux - a rate measurement of contaminant mass moving through a specific defined area, expressed as mass/time/area (e.g., kg/yr/m2).

(6) Mass discharge – the sum of mass flux across the plume and is therefore expressed as mass/time (e.g., kg/yr) – unit used to express Total Maximum Daily Load (TMDL).

(7) Dimensions of a PRB – Length, height (depth) and flow through thickness.

(8) Hydraulic Capture Zone of the PRB – groundwater flow captured by the PRB from upgradient areas of the watershed.



From ITRC 2011

2. Introduction

AECOM is providing water quality and wastewater planning and engineering services to the Town of Orleans (the Town) to reduce excessive nitrogen discharges to the Town's ponds, estuaries and embayments. The Project represents the first to implement a "Hybrid" approach under the Cape Cod 208 Water Quality Plan, recently approved by both USEPA and MassDEP. The Project consists of conceptual and preliminary design to update the Comprehensive Wastewater Management Plan (CWMP) completed by the Town in 2011 to reflect the Consensus Plan (Water Quality Management Plan) developed by the Town in 2015. The Project goal is to minimize the proposed sewered footprint (area of Town and number of properties to be sewered) to the greatest extent possible by maximizing the use of several non-traditional technologies (Coastal Habitat Restoration, Aquaculture, Floating Constructed Wetlands, and PRBs). Figure 1 shows a version of the Consensus Plan Map (February 2015) showing anticipated locations of PRBs.

Major watersheds in the Town of Orleans include the Nauset Inlet, Pleasant Bay, Cape Cod Bay, and Atlantic Ocean watersheds. The groundwater system comprising these watersheds is part of the Monomoy Lens of the Cape Cod Aquifer (Walter et. al., 2004). Approximately 80% of the residential homes and many of the commercial businesses in Orleans are in the Nauset Inlet and Pleasant Bay watersheds (Wright-Pierce, 2010). These watersheds are characterized by numerous sub-watersheds contributing groundwater discharge to salt ponds and inlets. Nitrogen loading from point and non-point sources in the watersheds is impacting surface water quality. PRBs can intercept and remove part of this nitrogen load from the groundwater system.

Removing nitrogen from groundwater can be mediated by naturally occurring denitrifying bacteria in the aquifer that gain energy from dissolved organic carbon or other food substrates and consume nitrate in their respiration. This process of bacterial metabolism results in the conversion of nitrate to inert nitrogen gas (denitrification) and requires both anoxic conditions (dissolved oxygen less than 1 mg/L in groundwater) and sufficient food substrate for bacterial growth. PRBs provide the food substrate to deplete oxygen levels, resulting in conditions that favor denitrifying bacteria, and food substrate to promote their growth.

The PRB treatment zone is located in groundwater below the water table. Nitrate is removed in place in the ground (in-situ) as groundwater flows through the thickness of the permeable barrier. The nitrogen load removed by the PRB comes from water and wastewater recharged to the groundwater that contains nitrogen upgradient and within the hydraulic capture zone of the barrier.

The system is permeable because the food substrates and other amendments added do not interfere with groundwater flow, and nitrate is removed as groundwater passes through. A PRB would be most cost effective where groundwater transport of nitrogen is significant, with higher nitrate concentration and a relatively fast groundwater velocity, resulting in a high mass flux of nitrate through the treatment zone. It is this mass flux of nitrogen that contributes to nitrogen loading to downgradient surface waters and needs to be reduced.

There are several design concepts and variations for PRBs. Systems and amendments are engineered to optimize conditions for groundwater treatment within the PRB treatment zone depending on site conditions such as nitrate concentrations, groundwater chemistry, and groundwater velocity. PRB installation may be via trench excavation or soil boring. Trench systems typically utilize solid amendment media such as wood chips. Boring methods allow delivery of either liquid or solid amendments in the subsurface via direct placement or injection. There are also design concepts using soil borings to place electrodes for generation of amendments in the subsurface with electrochemical methods.

Trench installations require excavation to place the reactive substrate in the subsurface. Standard construction excavation equipment would not be capable of reaching targeted depths greater than 30 feet below grade. Nitrate plumes in the aquifer are expected to extend 30 feet or more below the water table and depth to the water table is variable from location to location. Trenching using a specialized one-pass trencher could go deeper, up to a total of approximately 40 to 50 feet below grade. The one-pass method cuts a trench with specialized large excavators that simultaneously backfill with the reactive materials through a delivery box that extends to the bottom of the trench. The trencher pulls this trench box along while a conveyor system keeps the box full of reactive material. Excavations must be located very close to or in natural resource areas adjacent to surface waters to possibly reach effective depths. Working in natural resource areas would increase permitting requirements and costs. Installation of trenches may also cause major disruption and abutter concerns may be significant. Trench systems located very close to surface water resource areas may not provide sufficient downgradient travel time for stabilization of groundwater chemistry before groundwater discharge to the surface water. Trenching options would generate a significant volume of soil that would need to be disposed of off-site and would likely also require an area for temporary stockpile staging.

An alternative approach for installation is to use soil borings for in-situ delivery of reactive materials. The most common amendments for this application are slow-release organic carbon electron donor substrates, such as food-grade emulsified soy bean oil. These soil boring PRB installations could be located upgradient away from resource areas and installed with minimal disturbance at the ground surface. The soil boring methods and emulsified soil bean oil have been commonly applied for in-situ treatment of nitrate and other groundwater contaminants at thousands of sites that have been closely monitored.

Denitrification PRB construction utilizing soil borings to place solid substrates such as elemental sulfur or for the placement of electrodes to generate amendments in the subsurface with electrochemical methods are more experimental but show promise.

PRB demonstration objectives generally include proof of performance and identifying design and operational factors that will influence cost and successful implementation and operation at full scale.

Specific objectives for PRB demonstration include:

(1) Conducting testing representative of full scale application;

(2) Providing proof of nitrogen concentration and load reduction to extrapolate to (TMDL) reduction targets at full scale;

(3) Obtaining data for engineering evaluations and full scale cost estimates;

(4) Confirming time frame for technology performance; and

(5) Demonstrating programs for performance, compliance monitoring, and assessment of treated water quality.

3. Demonstration Site Identification Process

Potential PRB locations identified on the Consensus Plan Hybrid Map and additional locations were further evaluated by the AECOM PRB Technical Team (AECOM and MT Environmental Restoration) as potential demonstration sites. The specific methodology used for detailed site evaluations included the following steps:

- Review of potential PRB locations developed through the Consensus Planning process;

- Review of Nauset, Pleasant Bay and Cape Cod Bay watersheds to identify potential demonstration locations that may not have been previously identified or variations on the identified locations;
- Assessment of potential PRB nitrogen reductions with the online WatershedMVP Multi-variant Planning tool developed by the Cape Cod Commission (http://www.watershedmvp.org/);
- Initial field visits to potential sites;
- Review of existing soil and/or groundwater quality data, where available;
- Discussion of potential demonstration sites with Town of Orleans officials;
- Refinement of criteria to be used in the Site Selection Matrix;
- Submission of the Site Selection Matrix to Town of Orleans for review;
- Ranking of sites based on criteria using Site Selection Matrix;
- Reviewing preferred PRB demonstration sites that resulted from the Site Selection Matrix process; and
- Recommending site locations for additional field investigation and Work Plan cost estimates.

This Technical Memorandum reports on the findings of these tasks.

It is important to note that while efforts were made to evaluate all available information regarding the geology and hydrogeology of potential PRB demonstration locations, site specific information is very limited. The local direction of groundwater flow has been assumed based on regional groundwater contours from the 1995 Cape Cod Commission Orleans Water Table Mapping Project (Cape Cod Commission, 1995). Water table elevations may vary locally resulting in deviations in local groundwater flow direction that affect the hydraulic capture zone of a PRB and the transport of treated groundwater downgradient.

Collection of limited site specific information, through investigations including the installation of groundwater monitoring wells and groundwater sampling will be completed by AECOM in 2016 on selected sites. The investigations will be used to assess groundwater flow directions, groundwater chemistry, and the vertical distribution of nitrogen compounds in groundwater at key locations. Information generated in these assessments will be reviewed and incorporated into this Technical Memorandum.

4. Selected PRB Sites for Characterization and Evaluation

Eight (8) potential locations for PRB demonstration were considered in detail including:

A - Main Street and Tonset Road (Main Street);

B - South Orleans Road at Tonset/Eldredge Parkway (Route 28 site);

C - Town Cove Gibson Road;

D - Namequoit Road;

E - Town Landfill;

F - Paw Wah Pond;

G - Rock Harbor Road Area; and

H - Kescayo Gansett Pond (Lonnie's Pond).

The eight locations are shown on Figure 2.

Information regarding selected potential PRB demonstration sites is provided in Section 4a. for use in assessing the locations against Site Suitability Criteria presented in Section 5. Based on the eight (8) locations identified above, thirteen (13) preliminary full scale PRB scenarios were evaluated for nitrogen reduction with WatershedMVP to assess the benefit and efficiency of various theoretical PRBs at full length. In some cases both shallow and deep groundwater treatment scenarios were considered. The WatershedMVP tool developed by the Cape Cod Commission evaluates nitrogen load based on land use in the watershed and was used to predict nitrogen load reductions based on hydraulic capture zone of a theoretical PRB at each site. A summary of WatershedMVP nitrogen load estimates for each scenario is included in Table 1.

a. Description of Potential Sites in the Nauset watershed

The Massachusetts Estuaries Project (MEP) target nitrogen load reduction for the Nauset Harbor system is approximately 8,600 kg N/year, while the Town Cove sub-embayment target load reduction is approximately 6,700 kg N/year (Howes, et.al. 2012). PRBs may be implemented to remove a portion of these nitrogen load reduction targets.

Four potential locations were identified in the Nauset watershed with projected groundwater discharge to Town Cove including the Main Street site, the Route 28 site, the Town Landfill, and the Gibson Road site.

(1) Main Street and Tonset Road (Main Street Site)

The Main Street site is located close to Town Cove (~350 feet), and the full-scale PRB was projected to extend 2,250 feet along Main Street and Tonset Road in an area of mixed residential and commercial development. The depth to groundwater along Main Street is approximately 14 ft. below ground surface (bgs), and the depth to groundwater along Tonset Road is approximately 32 ft. bgs. WatershedMVP was used to estimate intercepted nitrogen load based on land use in the upgradient area. The WatershedMVP assessment calculated that the PRB would capture the nitrogen load from all upgradient areas of the watershed totaling an estimated 965 kilograms per year (kg/yr). Based on the WatershedMVP calculated output, assuming an effective nitrogen load reduction of 75%, a full-scale PRB would remove approximately 720 kg/yr or an estimated 0.32 kg/yr/ft of PRB length. This estimate did not include nitrogen in groundwater originating at the upgradient Orleans Town landfill that may add substantially to the projected nitrogen load intercepted.

(2) South Orleans Road at Tonset/Eldredge Parkway (Route 28 Site)

The Route 28 site is located approximately 1,200 feet upgradient of Main Street along Route 28 (South Orleans Road) near the intersection of South Orleans Road, Tonset Road, and Eldredge Parkway. This site is considered a variant of the Main Street site, and the results of demonstration at Route 28 could also be applied to full scale implementation at the Main Street Site. The land between these two potential PRBs includes a wooded swamp area that may have local effects on the direction of groundwater flow that may affect the layout of a PRB demonstration on Main Street.

Site specific groundwater data is available from previous investigations. Several groundwater monitoring wells installed for a separate investigation at the Police Station have been identified. The depth to groundwater at Route 28 is approximately 30 ft. The full-scale PRB is projected to extend 900 feet along Route 28 and in an area of mixed residential and commercial development with Town facilities including the Orleans Police Station and adjacent Eldredge Park. This PRB would capture the nitrogen load from all upgradient areas of the watershed calculated with WatershedMVP to total an estimated 710 kg/yr. Based on the WatershedMVP calculation, assuming a nitrogen load reduction of 75%, the PRB would remove approximately 530 kg/yr or 0.59 kg/yr/ft. of PRB, indicating this location could potentially remove the most nitrate from the groundwater, and therefore be the most cost effective, on a per foot basis. This location is also potentially in the groundwater flow path of nitrogen originating at the upgradient Orleans Town landfill; however, this estimate does not include nitrogen sources from the landfill that may add substantially to the projected nitrogen load.

(3) Town Cove Gibson Road

The Gibson Road site is located on the east side of Town Cove on Gibson Road. The full-scale PRB was projected to extend 2,500 feet along Gibson Road in an area of residential development. Based on regional maps the depth to groundwater is approximately 23 ft. but variable with rolling topography. The WatershedMVP model estimates that the PRB would capture the nitrogen load from all upgradient areas of the watershed totaling approximately 810 kg/yr. Based on the WatershedMVP output, assuming a nitrogen load reduction of 75%, the PRB would remove 610 kg/yr or 0.24 kg/yr/ft. of PRB.

(4) Orleans Town Landfill Site

The Orleans Town Landfill site consists of approximately 20 acres located off Lots Hollow Road near the top of the Nauset watershed. Site specific groundwater data is available from previous investigations. The depth to groundwater is approximately 45 ft. bgs at the lowest point of land elevation at the landfill but increases significantly downgradient as the land surface is higher. A previous review of groundwater monitoring data from monitoring wells routinely sampled at the landfill indicated significant concentrations of nitrate in groundwater downgradient of the landfill and former septage lagoons (MT Environmental Restoration, April, 2015). The nitrogen load from the landfill cannot be predicted with WatershedMVP because it uses parcel based land use and water supply use to predict nitrogen loads rather than actual groundwater data that would be required for this type of location. While insufficient data is available to precisely project nitrate mass transport in groundwater from the landfill it is likely very significant. Recent groundwater data from the routine landfill monitoring well sampling program (October 2015) included the first data quantifying total nitrogen in addition to nitrate in samples from landfill monitoring wells. These data indicated significant nitrate concentrations in shallow groundwater total nitrogen concentrations in deeper screened wells where nitrate concentrations were relatively low. These data indicating a potential plume of ammonia (not directly analyzed) in the deeper groundwater that cannot be treated by denitrification without an aerobic step to first convert the ammonia to nitrate.

b. Description of Potential Sites in the Pleasant Bay Watershed

The target nitrogen load reduction for the Pleasant Bay System is approximately 17,000 kg N/year (Howes, et.al. 2006). The Pleasant Bay system has numerous inlets and connected salt ponds, each with its own sub-watershed. Pleasant Bay has been designated An Area of Critical Environmental Concern (ACEC) under MGL ch. 21A Section 2 (7). The effect of designation as an ACEC compels the State to ensure that activities in or impacting the area are carried out so as to minimize adverse effects. Locating a PRB within an ACEC would result in additional permitting costs and potentially limited public acceptance. The Pleasant Bay ACEC extends inland to the 10-foot contour plus 100 feet.

Three potential locations were assessed in the Pleasant Bay watershed.

(1) Namequoit Road

The Namequoit Road site is located along Namequoit Road upgradient of the Namequoit River, the inlet to Areys Pond off Pleasant Bay. This location would be within the Pleasant Bay ACEC. The full-scale PRB was projected to extend 1,100 feet in an area of residential development. The depth to groundwater ranges approximately 25 to 55 ft. along the proposed PRB length due to uneven topography. The PRB would capture the nitrogen load from all developed upgradient areas of the watershed with the WatershedMVP estimate calculating approximately180 kg/yr. Based on the WatershedMVP output, assuming a nitrogen load reduction of 75%, the PRB would remove approximately 130 kg/yr or 0.12 kg/yr/ft. of PRB length.

(2) Paw Wah Pond

The Paw Wah Pond site is located along Lockwood Lane, a private unpaved road upgradient of Paw Wah Pond and within the Pleasant Bay ACEC. The full-scale PRB was projected to extend 800 feet in an area of residential development. The depth to groundwater is approximately 21 ft. bgs. The PRB would capture the nitrogen load from all upgradient areas of the watershed with the WatershedMVP estimate totaling approximately 110 kg/yr. Based on the WatershedMVP output, assuming a nitrogen load reduction of 75%, the PRB would remove approximately 80 kg/yr or 0.10 kg/yr/ft. of PRB length.

(3) Kescayo Gansett Pond/Lonnie's Pond

The Lonnie's Pond site is located along Herring Brook Road within the Pleasant Bay ACEC. The full-scale PRB was projected to extend 1000 feet in an area of residential development. The depth to groundwater ranges from approximately 2 to 22 ft. bgs, with deepest depth to groundwater at the northern end. The PRB was projected to capture the nitrogen load from the watershed with the WatershedMVP estimate totaling 120 kg/yr. Based on the WatershedMVP output, assuming a nitrogen load reduction of 75%, the PRB would remove approximately 90 kg/yr or 0.09 kg/yr/ft. of PRB length.

c. Description of Potential Sites in the Cape Cod Bay Watershed

One potential location was assessed in the Cape Cod Bay watershed. Inner Cape Cod Bay is also an ACEC with the landward extent to the 10-foot contour.

(1) Rock Harbor Road Area Site

The Rock Harbor Road Area Site location evaluated is along Captains Row, an unpaved road off Rock Harbor Road extending approximately 700 ft. east to west upgradient of Rock Harbor. The location is outside the Cape Cod Bay ACEC in an area of residential development. The depth to groundwater ranges from approximately 10 to 20 ft. bgs. The PRB was projected to capture approximately 180 kg/yr with WatershedMVP. Based on the WatershedMVP output, assuming a nitrogen load reduction of 75%, the PRB would remove approximately 130 kg/yr or 0.19 kg/yr/ft. of PRB length.

5. Site Suitability Criteria and Analysis

a. Site Selection Matrix

A Site Selection Matrix was developed for objective evaluation of selected PRB sites. The Matrix includes criteria for Site Suitability, Permitting, Project Evaluation and Other/Overriding Considerations. These criteria address environmental, land use and implementation features of the proposed demonstration locations. Permitting criteria assess regulatory requirements and potential conflicts related to the proposed demonstration locations. Project evaluation criteria evaluate the benefits gained from a proposed demonstration site. Other/Overriding Considerations refers to other superseding issues that support or prevent a demonstration at a given site.

The Site Selection Matrix includes the following criteria:

Site Suitability:

- Downgradient Water Use – Wells (PRBs locations should not be located where potable water supply wells are located nearby and downgradient)
- Topography (significant changes in elevation may affect construction and monitoring)
- Depth to Groundwater (deeper water table increases costs and may affect feasibility)
- Groundwater Nitrogen Profile (nitrate concentrations and concentrations change with depth in groundwater -addresses feasibility)
- Groundwater Flow Direction and Velocity (necessary for orientation of PRB and assessing nitrate flux and cost effectiveness)
- Ease of Access/Use of Property
- Representativeness (transferability of lessons learned from demonstration testing/meets target conditions for a PRB)

Permitting:

- Outside ACEC, Upland Areas (reduced permitting requirements for PRB placement)
- Abutter Compatibility
- Property Ownership/Road Layout (ease of access for PRB placement)
- Utility Conflicts (feasibility for PRB placement)

Project Evaluation:

- Nitrogen Removal Efficiency (utility and cost effectiveness)
- Overall Ease of Monitoring (cost benefit and enhancement of performance data collection to meet demonstration goals)
- Accessible Well Locations
- Quantity/Quality of Existing Information (cost benefit)

Other/Overriding Considerations:

- Community Acceptability
- Potential for Public Education
- Potential for Watershed/Estuary Impacts (distance from surface water and wetland resource areas/ water use considerations)
- Funding Potential
- Potential for Full Scale Implementation

b. Analysis

The PRB Technical Team collected site specific information, conducted site visits, and evaluated the potential performance effectiveness of selected PRB locations with the WatershedMVP utility. A ranking system was then developed to quantify how well each site met a specific criterion. The point-based system used is as follows:

- Good = 1 point
- Neutral = 0 points
- Poor = -1 point

A **good** ranking (1) was assigned if the criterion could be met fully.

A **neutral** ranking (0) was assigned if the criterion could be met in part, but there were some potential issues and/or difficulties.

A **poor** ranking (-1) was assigned if the criterion could not be met.

For the Site Suitability criteria, if a site was fully suitable based on the criterion being ranked, it was assigned a numerical value of 1. If the site was mostly suitable based on the criterion being ranked. It was assigned a ranking of 0 and if the site was mostly unsuitable, it was assigned a ranking of -1.

For the Permitting criteria, if a site was likely to be permitted and attain all regulatory approval based on the criterion being ranked, it was assigned a numerical value of 1. If the site was likely to be permitted, but there were potential issues related to the criteria, it was assigned a ranking of 0. If the site was more difficult to permit and receive all regulatory approval, it was assigned a ranking of -1.

For the Project Evaluation criteria, if a site was likely to produce a representative PRB demonstration based on the criterion being ranked, it was assigned a numerical value of 1. If the site was probably able to produce a representative demonstration it was assigned a ranking of 0. If a demonstration was unlikely to be representative at a site it was assigned a ranking of -1.

Quantitative rankings were tabulated in the Site Selection Matrix. Results of the PRB site evaluation are discussed in Section 6.

6. Findings and Recommendations

The results of the site suitability evaluation are as follows:

7. References

Cape Cod Commission 1995, Orleans Water Table Mapping Project

Howes B., S. W. Kelley, J. S. Ramsey, R. Samimy, D. Schlezinger, E. Eichner (2012). Linked Watershed-Embayment Approach to Determine Critical Nitrogen Loading hresholds for the Nauset Harbor Embayment System Towns of Orleans and Eastham, Massachusetts

Howes B., S. W. Kelley, J. S. Ramsey, R. Samimy, D. Schlezinger, E. Eichner (2006).

Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Pleasant Bay, Chatham, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA.

MT Environmental Restoration and GHD Inc., April 2015, Orleans landfill nitrate data evaluation report.

Walter, D.A., Masterson, J.P., and Hess, K.M., 2004, Ground-water recharge areas and travel times to pumped wells, ponds, streams, and coastal water bodies, Cape Cod, Massachusetts: U.S. Geological Survey Scientific Investigations Map I-2857, 1 sheet [http://pubs.usgs.gov/sim/2004/2857/].

Wright-Pierce, December 2010, Town of Orleans Comprehensive Wastewater Management Plan and Single Environmental Impact Report.

270 Parcels
96,500 GPD

286 Parcels
45,600 GPD

178 Beach Road

223 Beach Road

Tri-Town Site

9 West Road

Potential Reclaimed Water Line

Clover Leaf Route 6A

29 Baker's Pond Road

Potential Disposal/Treatment Site in Brewster Site A

Potential Disposal/Treatment Site in Brewster Site B

Rock Harbor
Little Namskaket
Namskaket
Cedar Pond
Town Cove
Mill Pond
Meetinghouse Pond
Uncle Harvey's Pond
Upper River
Crystal Lake
Lonies Pond
Pochet
Baker's Pond
Pilgrim Lake
Lower River
Namequoit River
Arey's Pond
Uncle Israel's Pond
Twinings Pond
Sarah's Pond
Shoal Pond
Meadow Bog Pond
Deep Pond
Quanset
PLEASANT BAY
HARWICH
CHATHAM

Legend

- Floating Constructed Wetlands
- Coastal Habitat Restoration
- PRB_hybrid
- Aquaculture Area
- Coastal Habitat Restoration Area
- Floating Constructed Wetlands Area
- Potential Reclaimed Water Line
- Potential Reclaimed Water Sites
- Landfill
- 4 Nauset Middle School
- B Tri-Town
- Downtown Sewered Area
- Meetinghouse Sewered Area

Potential Disposal/Treatment Sites

- Site 5 - Tri-Town Disposal
- Site 6 - Tri-Town Disposal
- Site 7 - Tri-Town Disposal
- Site 15 - Meeting house/Pochet Treatment/Disposal
- Site 16 - Meeting house/Pochet Treatment/Disposal
- Site 21 - S. Orleans Treatment/Disposal
- Watershed Boundary
- Subwatershed Boundary

General Notes
1. 25% Nitrogen reduction from fertilizer management is applied to all watersheds.
2. All non-sewered area septage to be hauled and treated at the Tri-Town facility.
3. Sludge from decentralized treatment systems to be hauled and treated at the Tri-Town facility.
4. Wastewater flows based on current parcel water usage.
5. Map locations shown for Non-Traditional technologies illustrate scale.Specific siting will occur during project planning and design.

Stantec

ORLEANS HYBRID VERSION 3
WQAP MEETING 2-11-15

TOWN OF ORLEANS
MASSACHUSETTS

FEBRUARY, 2015

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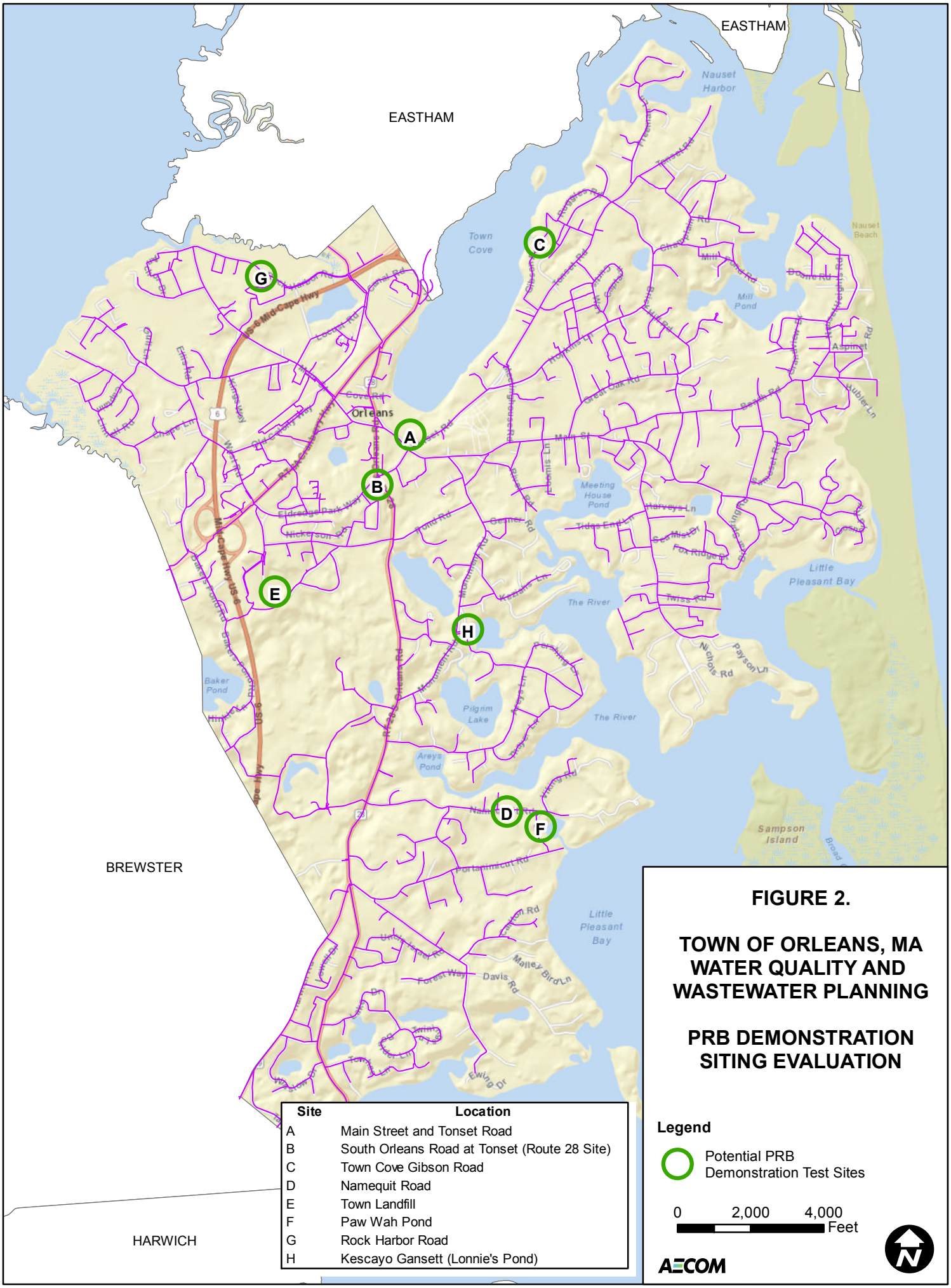

Site	Location
A	Main Street and Tonset Road
B	South Orleans Road at Tonset (Route 28 Site)
C	Town Cove Gibson Road
D	Namequit Road
E	Town Landfill
F	Paw Wah Pond
G	Rock Harbor Road
H	Kescayo Gansett (Lonnie's Pond)

FIGURE 2.

TOWN OF ORLEANS, MA WATER QUALITY AND WASTEWATER PLANNING

PRB DEMONSTRATION SITING EVALUATION

Legend

Potential PRB Demonstration Test Sites

0 2,000 4,000 Feet

AECOM

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Table 1 WatershedMVP PRB Scenario Summary													
Scenario Number	1	2	3	4	5	6	7	8	9	10	11	12	13
Description	Site A Town Cove Main and Tonset Deep	Town Cove Tonset Only	Town Cove Main St Only	Town Cove Main and Tonset Shallow	Site B Town Cove Route 28	Town Cove Gibson and Ruggles	Town Cove Ruggles Shallow	Site C Town Cove Gibson Deep	Town Cove Gibson And Ruggles Shallow	Site H Lonnies Pond Herring Brook Way	Site D Namequoit River	Site F Paw Wah Pond	Site G Rock Harbor Rd Captains Way
Total Properties In PRB Capture Area	192	95	97	96	104	272	55	217	137	36	38	23	38
Total Unsewered Properties In PRB Capture Area	192	95	97	96	104	272	55	217	137	36	38	23	38
MVP Estimated Nitrate Load (Sewer, Fert, Storm) In kg/yr	965	565	400	487	708	1,014	201	813	560	122	178	111	178
Nitrate Load From Other Sources (kg/yr)	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Nitrate Load (kg/yr)	965	565	400	487	708	1,014	201	813	560	122	178	111	178
Percent Nitrate Reduction From PRB	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%
Nitrate Load Removed by PRB (kg/yr)	724	424	300	365	531	760	151	609	420	91	134	83	134
PRB Length (Feet)	2,250	1,300	950	2,250	900	3,725	1,225	2,500	3,725	1,000	1,100	800	700
Nitrate Load Removed Per Foot of PRB (kg/yr/ft)	0.322	0.326	0.316	0.162	0.590	0.204	0.123	0.244	0.113	0.091	0.122	0.104	0.191
Relative Estimated PRB Depth into Aquifer	Deep	Deep	Deep	Shallow	Shallow	Deep	Shallow	Deep	Shallow	Deep	Deep	Shallow	Deep