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Memorandum

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Subject	**Town of Orleans, MA** **Water Quality and Wastewater Planning** **Task Number 3.b – Non Traditional Demonstration Projects** **50% Draft Technical Memorandum for Site Characterization and Evaluation for Floating Constructed Wetlands**
Project Number	60476644
From	Thomas Parece, P.E., AECOM Project Manager
Date	January 8, 2016

1. Background

a. Purpose

Floating Constructed Wetlands (FCW) are one of the non-traditional (NT) tools being tested by the Town of Orleans to determine the efficacy in managing nitrogen within the Town's water resources. Orleans' water resources have been degraded due to nutrient enrichment, primarily from the disposal of wastewater. The intent of including the FCWs as part of the Nitrogen management solution is to use the constructed ecosystems to mimic natural floating wetlands to aid in nutrient removal and potentially provide other potential ecosystem services such as wave attenuation, habitat and food structure and refuge for fish and other marine life.

The Site Characterization and Evaluation Technical Memorandum documents the process used to identify, evaluate, rate, rank and ultimately recommend specific demonstration sites to test the efficacy of FCW to remove nitrogen from the estuarine waters located within the Town of Orleans. This Memorandum includes the following:

- Description of the initial process employed to develop the Orleans Consensus Plan and associated potential demonstration sites;
- Next steps taken in the process of evaluating demonstration sites;
- Review of available data to understand current site conditions and evaluate potential demonstration sites;

- Evaluation, rating and ranking of sites based on the site selection matrix and criteria; and
- The recommended demonstration site and the rationale for its selection.

In addition, key terms are defined including the categories of data that were evaluated. The site selection criteria and rating system used to assess potential demonstration sites are also explained.

The purpose of this documentation is to provide a transparent and objective assessment of possible locations in Orleans to site FCW Non-Traditional technology demonstration projects. The assessment will be used to select the best possible site for preliminary engineering, which will include drawings, preliminary specifications, cost estimates, funding sources and monitoring plans.

b. Glossary of Floating Constructed Wetlands Terms and Key Design Features

To establish a consistent meaning of FCW in the context of this Technical Memorandum, this term is defined as follows:

FCWs are man-made rafts that float on the water's surface and are planted with native plants. The FCWs provide habitat and surface-area for a wide range of naturally-occurring attached growth microorganisms and invertebrates. As water passes through the system, nitrogen, phosphorus, biological oxygen demand, total suspended solids and fecal coliforms can be reduced.

The following core design principals that will be followed in the design of the FCWs are to:

- Utilize natural, low-tech treatment technologies where possible.
- Minimize energy use and mechanical system complexity.
- Incorporate educational and interpretive value into the system.
- Develop systems that are easy to maintain and operate to enhance long-term viability.

The key feature of FCWs is their high surface-area-to-footprint ratio, which enables them to perform functions similar to a natural wetland treatment system but in the fraction of the space. The FCW can be designed into any shape or size, but a typical section is rectangular. Any number of sections can then be connected together by cable to create a unit. The FCWs will be anchored to stay in one area of the surface water body, but rise and fall naturally with the tide. FCWs have a draft of about 6 inches, and would likely be located in water depths of approximately 5 - 6 feet. This would minimize disturbances to the benthic environment.

To provide an understanding of FCW, a few photos and diagrams of the systems are provided below.

Jamaica Bay Floating Wetland Wave Attenuator

Baltimore Harbor Floating Constructed Wetland

Below, a diagram from a floating wetland system currently being studied in Baltimore Harbor is provided which illustrates some of the functions provided by an FCW system.

FCWs remove pollutants from the water column by four main processes: physical, biogeochemical, microbial and plants. The larger surface area created by the plant roots increases sedimentation, microbial decomposition, nitrification and denitrification, and alters water chemistry.

Denitrification by FCWs occurs by producing anoxic conditions through the restriction of oxygen diffusion into the water column. Also, roots and plant litter act as sorption sites, with biofilms developing which increase denitrification rates and thus nitrate removal rates (Vymazal, 2007). Plant uptake accounts for a small percentage of nutrient (N and P) removal in FCWs (Dodkins and Mendzil 2014).

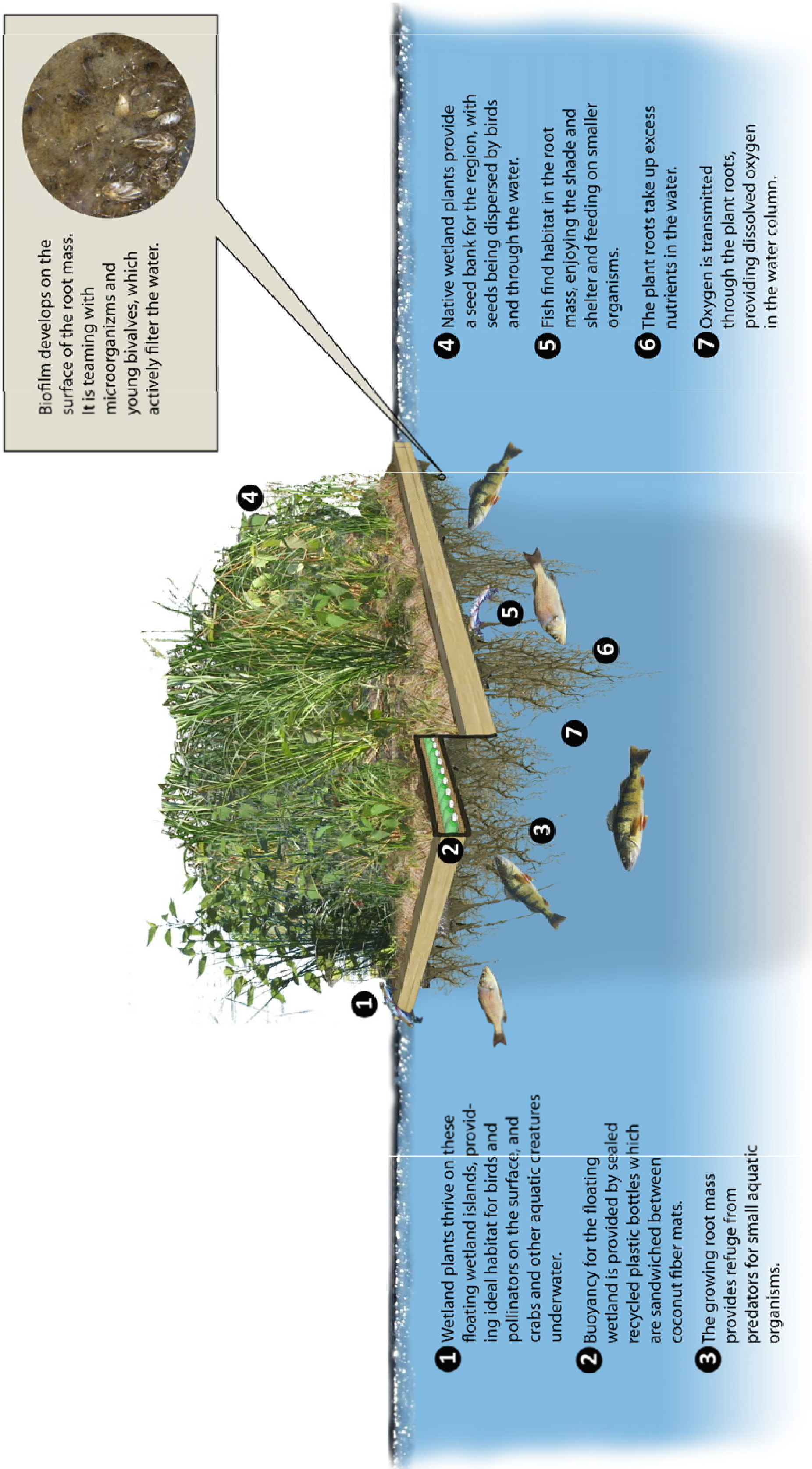
The FCW can be designed into any shape or size, but a typical section is rectangular. Any number of sections can be connected together by cables to create a unit.

The FCWs will be anchored to stay in one area of the surface water body, but rise and fall naturally with the tide. FCWs have a draft of about 6 inches, and would likely be located in water depths of approximately 5 - 6 feet. This would minimize disturbances to the benthic environment.

c. Goals and Objectives

The goal of this demonstration project is to evaluate the potential to use FCWs to:

- Reduce nutrients;
- Realize associated ecological and socioeconomic benefits;
- Evaluate uncertainties associated with the local climate and environmental conditions;



Cross Section of FCW used in Baltimore Harbor

- Assess local water quality and ecological benefits; and,
- Provide a case study to guide siting, design and monitoring of future projects.

The pilot project will be built as a temporary structure and will be monitored throughout the life of the project. If necessary, the structure can be removed at any time during the project or after the monitoring period is complete.

The immediate objectives of the proposed FCW demonstration project are to:

- Install temporary floating wetlands;
- Monitor the performance of the floating wetlands to reduce nitrogen in the surface water of the study area; and
- Infer quantitative decisions about the value of FCWs at meeting the long term goals of the Town of Orleans in reducing nitrogen in its water resources.

2. Introduction

a. Consensus Plan Overview

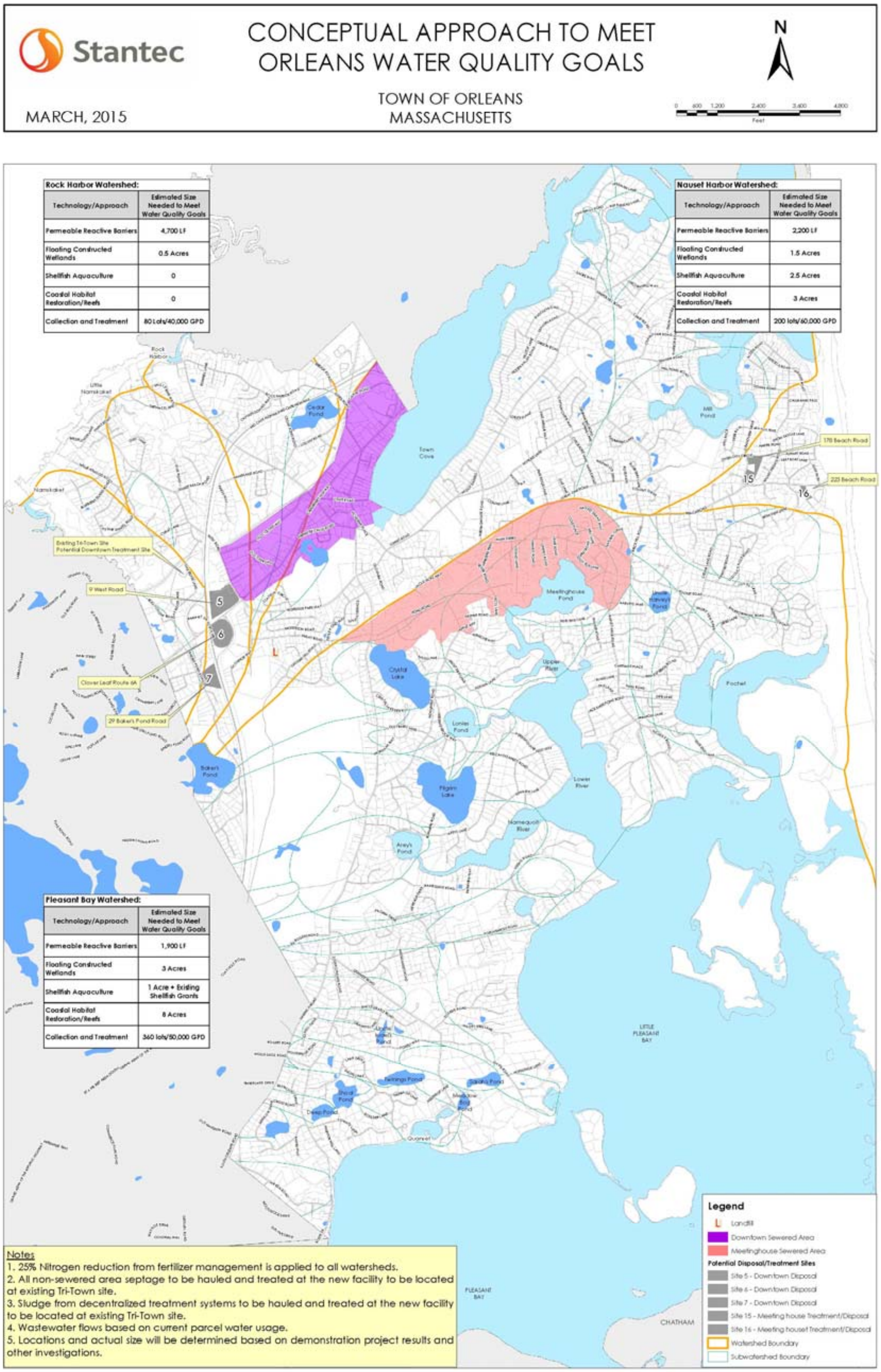
The Orleans Water Quality Advisory Panel, or OWQAP, was convened to achieve consensus and build widespread community support for a customized, affordable water quality management plan for the Town of Orleans. The panel consisted of stakeholder representatives (Orleans Selectmen and representatives of engaged citizen constituencies) and liaisons from key town boards and commissions, organizations, neighboring towns, and regional, state and federal partners. The OWQAP met for twelve half-day meetings starting in July 2014, all of which were open to public attendance and comment.

Potential alternative planning scenarios to meet water quality standards were developed for the OWQAP and presented at meetings and workshops. As discussed in further detail below in Section 2c, a Hybrid Plan was developed through an iterative process and included specific sites for the use of NT nitrogen removal technologies, including FCW, permeable reactive barriers, aquaculture and coastal habitat restoration. Once the feasibility of using FCW and other NT technologies as part of the Town's nutrient management strategy was established, the OWQAP decided that the final Consensus Plan would not specify exact site locations but instead focus on overall quantities of FCW and other NT technologies needed to remove the appropriate mass of nitrogen at the watershed level.

The resulting map (Figure 1), entitled Conceptual Approach to Meet Orleans Water Quality Goals (March 2015) shows the agreed upon water quality management plan and includes 1.5 acres of FCW in the Nauset Harbor watershed, 3 acres of FCW in the Pleasant Bay watershed, and 0.5 acre of FCW in the Rock Harbor Watershed. This map also specifies acreages for shellfish habitat and linear feet of PRBs.

b. Initial Process of Site Identification

As part of updating the 208 Plan, The Cape Cod Commission (CCC) created traditional and NT scenarios that would meet the regulatory requirements for nitrogen formalized as Total Maximum Daily Loads (TMDLs) for Orleans' impaired waterbodies. The traditional scenario for Orleans used centralized sewers exclusively. The NT scenario met nitrogen-removal goals through a subset of the many alternatives that are described in the 208 Plan's Technology Matrix. The subset of NT technologies in the Commission's NT Scenario included FCWs, permeable reactive barriers, coastal habitat restoration, shellfish aquaculture, fertigation, composting and urine-diverting toilets and innovative/alternative septic systems. In order to provide consistency with this



Rock Harbor Watershed:

Technology/Approach	Estimated Size Needed to Meet Water Quality Goals
Permeable Reactive Barriers	4,700 LF
Floating Constructed Wetlands	0.5 Acres
Shellfish Aquaculture	0
Coastal Habitat Restoration/Reefs	0
Collection and Treatment	80 Lots/40,000 GPD

Nauset Harbor Watershed:

Technology/Approach	Estimated Size Needed to Meet Water Quality Goals
Permeable Reactive Barriers	2,200 LF
Floating Constructed Wetlands	1.5 Acres
Shellfish Aquaculture	2.5 Acres
Coastal Habitat Restoration/Reefs	3 Acres
Collection and Treatment	200 lots/60,000 GPD

Pleasant Bay Watershed:

Technology/Approach	Estimated Size Needed to Meet Water Quality Goals
Permeable Reactive Barriers	1,900 LF
Floating Constructed Wetlands	3 Acres
Shellfish Aquaculture	1 Acre + Existing Shellfish Grants
Coastal Habitat Restoration/Reefs	8 Acres
Collection and Treatment	360 lots/50,000 GPD

established regulatory framework, the NT scenario developed by the Commission became the starting point for customizing a NT bookend for the OWQAP and consensus-building process.

This planning and design process for tailoring a NT bookend for Orleans included studying the information prepared by the CCC, and collecting and analyzing a significant amount of additional local data that were not reviewed as part of the regional planning process undertaken by the Commission. Local data from satellite images, GIS maps, groundwater maps, and coastal pond bathymetry data was reviewed, and then site visits both by land and by water were conducted to validate potential locations.

This local data collection and evaluation allowed the NT Bookend for Orleans to be based on key validated site parameters, to confirm that the NT technologies were feasible in their planned locations. In addition, a Technical Memorandum on NT Technologies (Appendix A) was prepared and submitted to the OWQAP. This Technical Memorandum detailed initial performance expectations, as well as key site and permitting considerations that should be used to verify the usefulness of these technologies for specific subwatersheds in Orleans.

The results of this detailed analysis and resulting initial locations for NT technologies were presented and discussed at the October 8, 2014 OWQAP Stakeholder meeting. Based on this technical review, as well as direction from the OWQAP, specific NT technologies were then selected to be used to create the “Hybrid Plan”, which is further discussed below.

c. Hybrid Plan Site Identification Criteria used during OWQAP Process

During a day-long OWQAP public workshop on December 17, 2014, the Hybrid Plan was presented, screened, and evaluated. This plan described a combination of traditional and non-traditional technologies that would meet the MEP load-reduction targets for nitrogen in each impaired waterbody. The OWQAP then formed three subgroups to discuss, evaluate and revise the Hybrid Plan. To assist in this process, a Technology Evaluation Decision Support Tool was developed to evaluate risks and benefits of each technology by subwatershed. Preliminary comparative costs were also presented on a relative dollars/kilogram of nitrogen removed basis. Spreadsheets with ratings and rankings for each subwatershed are included in Appendix B.

Ranked categories include:

- Nutrient removal certainty – Nitrogen (Saltwater) and Phosphorus (Freshwater);
- Implementation certainty;
- Other benefits including ecological, economic and social;
- Adaptability to uncertainty in nutrient-reduction goals and build-out;
- Contaminants of emerging concern removal; and
- Overall cost.

The list of potential water bodies identified during this process where FCW could be tested as a demonstration project included the following sites:

- Boland Pond
- Crystal Lake
- Lonnie’s Pond

- Mill Pond
- Namequoit River
- Paw Wah Pond
- Pilgrim Lake
- Pleasant Bay
- Pochet Neck
- Rock Harbor
- Quanset Pond
- Town Cove
- Upper River

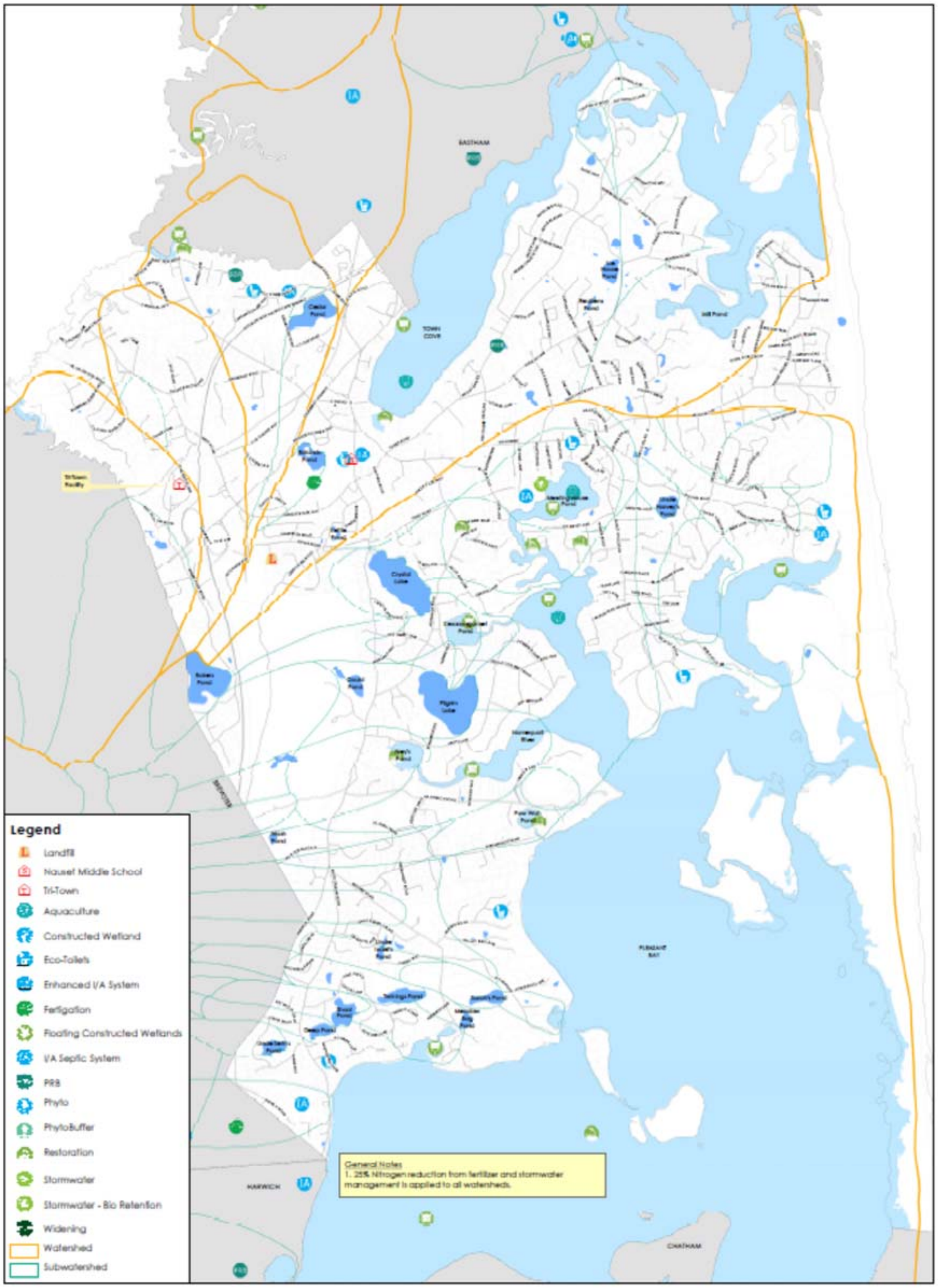
d. 2015 Site Reconnaissance

The initial FCW sites identified in the Hybrid Plan developed during the OWQAP process were reviewed by the AECOM team on maps and in the field through reconnaissance surveys in fall 2015. This reconnaissance review served to determine the final list of sites to be further evaluated as potential Demonstration Project locations.

Prior to the field visit, it was determined by the AECOM team that freshwater water bodies did not meet one of the criteria of the FCW demonstration projects since the results would not be replicable in the estuarine water bodies of the Orleans. As a result, Boland Pond, Crystal Lake and Pilgrim Lake were removed from the list of potential sites. Rock Harbor was also determined to not be feasible for purposes of the FCW demonstration project due to its narrow harbor and heavy boat traffic through the narrow harbor. These factors would not allow for a large square footage of FCW in Rock Harbor, and would also decrease the likelihood of successful establishment and survival of a FCW system due to the high potential for disturbance.

Therefore, the final list of sites reviewed as part of the 2015 reconnaissance field surveys, as shown on Figure 2 – Preliminary Non-Traditional Scenario Map (September 2014), were:

- Lonnie’s Pond
- Mill Pond
- Namequoit River
- Paw Wah Pond
- Pleasant Bay
- Pochet Neck
- Quanset Pond
- Town Cove



Stantec

CCC 208 PRELIMINARY
NON-TRADITIONAL SCENARIO MAP

TOWN OF ORLEANS
MASSACHUSETTS

SEPTEMBER, 2014

N

- Upper River

Based on the reconnaissance field survey, the list was further narrowed. Large water bodies with complex hydrological systems were removed from the list, as these features would make it difficult to measure nitrogen changes due to the installation of FCW. These two large waterbodies were Pleasant Bay and Town Cove. In addition, Mill Pond and Upper River were removed from the list due to the relatively small amount of available surface water space relative to the large number of boat moorings and boating activity in the area.

e. Sites Reviewed in Detail as Part of This Next Phase of Work

As a result of the previous efforts, and the reconnaissance field review of potential sites, the list of potential sites available for a FCW demonstration project were narrowed down to five sites, as listed below and shown on Figure 3 – Potential Floating Constructed Wetland Sites:

- Lonnie's Pond
- Namequoit River (with access through Arey's Pond)
- Paw Wah Pond
- Pochet Neck
- Quanset Pond

3. Description of Five Potential Sites

All sites selected as potential sites for the FCW demonstration project are small tributary sub-embayments of the Pleasant Bay Estuary, which is the largest embayment on Cape Cod. The tributary sub-embayments receive freshwater discharge, primarily in the form of groundwater discharge or groundwater fed surface water flow. Freshwater flows mix with incoming saltwater flows from twice daily tidal inundation. The sites then discharge to the Pleasant Bay Estuary during the twice daily outgoing tides. Due to these general characteristics, all sites have a number of general similar characteristics. Specific site conditions which were investigated are described below.

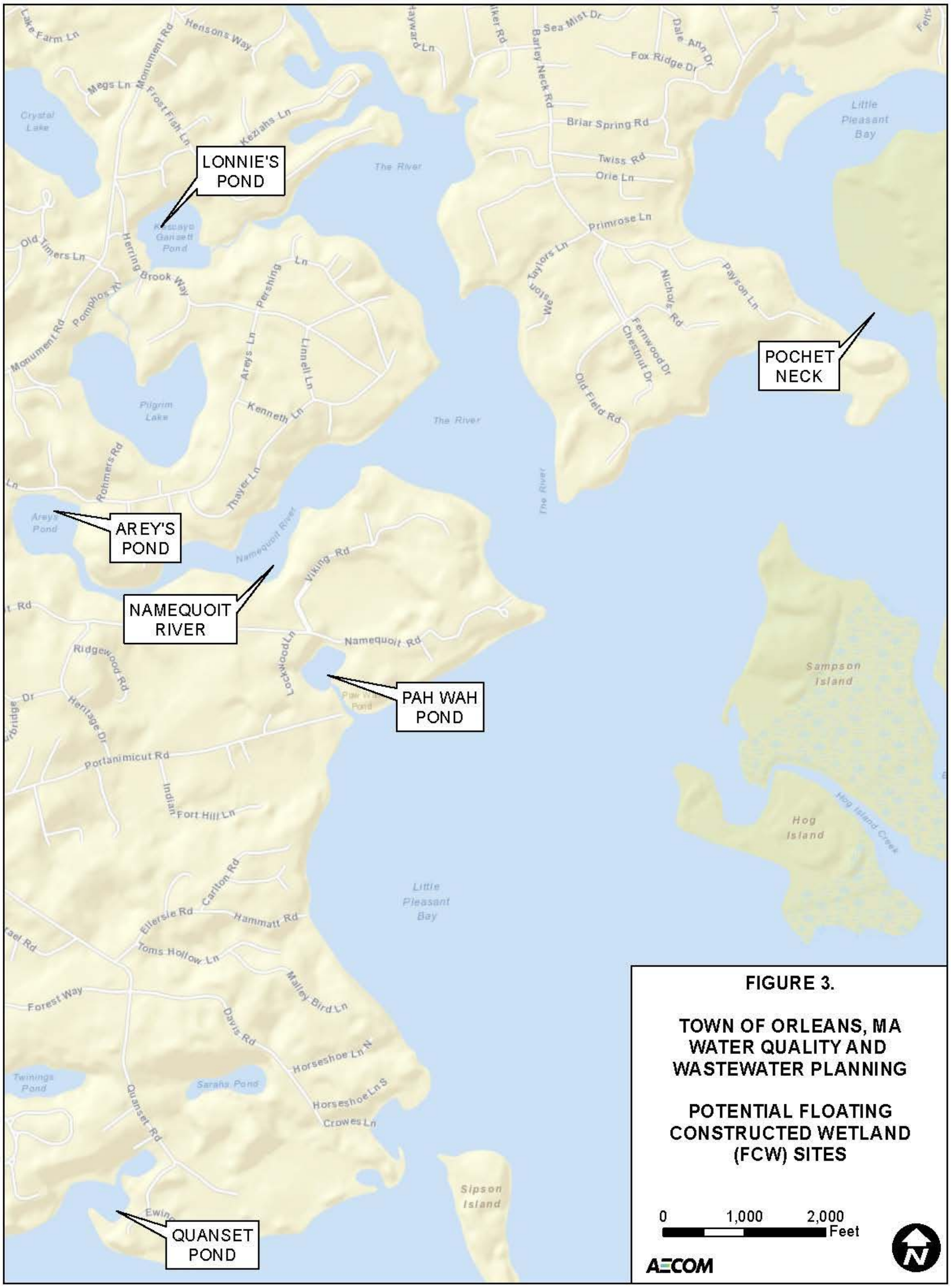
a. Common Parameters

All sites are located within the Pleasant Bay Estuary Area of Critical Environmental Concern, as designated in 1987 because of the area's extraordinary natural resources.

All sites have general tide levels which range from about five to six feet. Bathymetry data from the National Oceanic and Atmospheric Administration (NOAA 2015) indicates that the depth of the Bay and its sub-embayments at mean low tide is approximately two to three feet in most areas.

Surface water conditions for the sites do not vary from sub-embayment to sub-embayment; for example, salinity in the sub-embayments is generally within the range of 29 – 31 ppt and surface water temperatures, which are regulated by environmental conditions rather than site conditions, generally range from 21 – 24 degrees F (Alliance 2009, Cadmus Group 2015).

These sites are generally characterized as small enclosed basins (except for the Namequoit River which is ultimately hydrologically linked with Arey's Pond, a small enclosed basin), and as such are at risk of eutrophication from high nitrogen loads entering via direct groundwater seepage in addition to surface water inflows from adjacent sub-watersheds.



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Potential impairments to the water quality of these water bodies includes excess nutrients, low dissolved oxygen levels, high chlorophyll, excess macroalgae, and resultant degraded health of benthic fauna.

Because of the similarities in the six sites, the parameters reviewed for comparative purposes were targeted to differentiating features rather than common characteristics. Sites were reviewed to better understand site conditions and allow for comparison between sites centered on information about site hydrology (i.e. water flow), size of available surface water, and general surrounding water and land use conditions. These site parameters are identified below.

Water flow: Determination of how water circulates through the water body to determine inputs and outputs to the system.

Bathymetry: Depth of the water body.

Other water uses: Type and location of activities that occur in the water and on land near the site, that limit, or enhance, the ability to install the demonstration project.

Abutter interests/potential conflicts: Any known issues which might be raised within the community or by neighboring land use owners due to the presence of a demonstration project.

Available acreage: The amount of square footage available to a site for purposes of the demonstration project, given boating activity and other water uses in the area.

Access points/easement requirements: Whether or not a convenient, public location is available and could be used to access the site for installation, operations and maintenance of the demonstration project.

Land ownership: Whether or not the site has parcels that are privately owned that would limit or preclude use of the site for demonstration purposes.

b. Synopsis of Existing Conditions for Each of the Five Sites

Each of the five sites selected for further review as potential demonstration sites for the FCW are described below using the site parameters listed in the previous section.

(1) Lonnie's Pond is an intertidal salt water pond located off of the upper section of The River, located in the upper reaches of Pleasant Bay. The only channel access to The River and the Bay is narrow. The 2006 MEP report estimates that existing nitrogen loads are 4.3 kg/day.

Water flow - In addition to the twice daily tidal inundation at Lonnie's Pond, hydrologic inputs to the site include a stormwater pipe that drains into the northwest section of the pond, a cranberry bog that drains to the southwest, and a short herring run that links Pilgrim Lake with Lonnie's Pond. The groundwater flow is part of the Pleasant Bay Basin, within the Kescayogansett Pond, Lake and Stream subbasins, and flows from west to east.

Bathymetry – Bathymetric conditions for Lonnie's Pond, based on NOAA nautical maps, indicates depths within the pond ranging from 4 feet (along shore) to thirteen feet (at the mouth to The River), with an average depth of about nine feet. Off of the river, the channel leading to Lonnie's Pond is only about three feet in depth.

Other water uses – In the fall of 2015, there were a number of moorings observed within the pond, but there appeared to be space to place a large square footage of FCW near the discharge of the stormwater pipe. Also, in a powerpoint presentation provided to the Orleans Water Quality Advisory Partnership by Stantec in October 2014, the pond was noted as "relatively uncrowded." There is a public boat dock on the western edge of the site. Shell fishing within the pond is open to family permits only.

Abutter interests/potential conflicts – The land use around Lonnie's Pond is residential. The area is not densely populated, and areas along the tidal channel (Kent's Point) that links the pond with the bay are protected by the Orleans Conservation Trust.

Acreage available within water bodies – The surface water area of Lonnie's Pond is approximately 14.5 acres.

Access points/easement requirements – The site has access via the public boat landing located on the western edge of the site, and is noted as accommodating up to six parking spots.

Land ownership – The land below the waters is held in Public Trust by the Town of Orleans. Private residences surround the Lonnie's Pond and private ownership of the land extends to the low tide water line. Per the public trust doctrine, the public has the right to certain uses (fish, fowling, navigation) between the mean low and mean high tide lines. Based on consultation with the Orleans Town Assessor, the land below the mean low tide line is likely owned by the Town of Orleans, although this should be confirmed through legal review.

(2) **Namequoit River** is an intertidal embayment located off of the lower section of The River, within the upper reaches of Pleasant Bay. Namequoit River in general is narrow and shallow. The 2006 MEP report estimates that existing nitrogen loads to the entire Namequoit River are 17.8 kg/day.

Water flow - In addition to the twice daily tidal inundation flowing from the lower reaches of The River, the primary hydrologic input to the site is from Arey's Pond (which ranges in depth from six to fourteen feet). The groundwater flow is part of the Pleasant Bay Basin, within the Namequoit River subbasin, which flows from the southwest to the northeast.

Bathymetry – Bathymetric conditions for the Namequoit River, based on NOAA maps, indicate an average depth of one to two feet, but in some areas reaches four feet.

Other water uses – Docks and moorings line the shorelines of the Namequoit River and are privately owned. However, outside of the navigation channel, there appear to be small areas that are unused by dock, moorings and other boating activities. There is a boat yard located in Arey's Pond which appears to be heavily utilized and, therefore, there appears to be the potential for substantial boat traffic along the Namequoit River.

Abutter interests/potential conflicts – The land use around Namequoit River is largely low density residential with pockets of open space.

Acreage available within water bodies – The surface water area investigated for purposes of siting a FCW within Namequoit River is approximately 27 acres.

Access points/easement requirements – Access to Namequoit River would occur from Arey's Pond and would require a boat. The Town Landing at Arey's Pond is located off of Arey's Lane. No direct access to Namequoit River is available due to private land ownership along the water body.

Land ownership – The land below the waters is held in Public Trust by the Town of Orleans. Private residences surround the River and private ownership of the land extends to the low tide water line. Per the public trust doctrine, the public has the right to certain uses (fish, fowling, navigation) between the mean low and mean high tide lines. Based on consultation with the Orleans Town Assessor, the land below the mean low tide line is likely owned by the Town of Orleans, although this should be confirmed through legal review.

(3) Paw Wah Pond is a small, relatively deep, intertidal salt water pond located off of Little Pleasant Bay. The 2006 MEP report estimates that existing nitrogen loads to Paw Wah Pond are 5.6 kg/day.

Water flow – Paw Wah Pond receives twice daily tidal inundation from Little Pleasant Bay. Surface water flows from the surrounding residential areas into the low-lying pond. The Paw Wah groundwater subbasin is located just south of the Namequoit River subbasin, within the Pleasant Bay Basin, and flows similarly in a southwest to northeast direction.

Bathymetry – Bathymetric conditions for Paw Wah Pond, based on NOAA nautical maps, indicate an average depth of ten feet. The narrow channel from the bay to the pond appears to be about one foot in depth.

Other water uses – The Paw Wah Pond is noted as having little boat traffic, and did not appear to have many moorings when observed in the fall of 2015.

Abutter interests/potential conflicts – The land use around Paw Wah Pond is largely low density residential with pockets of open space. The Paw Wah Pond Conservation Area is an, undeveloped protected area located east of the pond.

Acreage available within water bodies – The surface water area within Paw Wah Pond is approximately 5.5 acres.

Access points/easement requirements – Access to Paw Wah Pond is available via a town owned parking area near the mouth of the pond, with limited parking.

Land ownership – The land below the waters is held in Public Trust by the Town of Orleans. Private residences surround Pah Wah Pond and private ownership of the land extends to the low tide water line. Per the public trust doctrine, the public has the right to certain uses (fish, fowling, navigation) between the mean low and mean high tide lines. Based on consultation with the Orleans Town Assessor, the land below the mean low tide line is likely owned by the Town of Orleans, although this should be confirmed through legal review.

(4) Pochet Neck is a narrow, shallow salt marsh dominated tidal subestuary located in the northeastern reaches of Pleasant Bay, just east of Pochet Island, Nauset Beach and the Atlantic Ocean. The 2006 MEP report estimates that existing nitrogen loads to the entire Pochet Neck bay are 9.4 kg/day.

Water flow – Pochet Neck receives twice daily tidal inundation from the upper reaches of Pleasant Bay via a very shallow channel. The Pochet Neck groundwater subbasin is located within the Pleasant Bay Basin, and flows northeast to southwest.

Bathymetry – Bathymetry data from NOAA indicates that this estuary is generally shallow; at mean low tide, the depth at the inlet is two feet. However, there are small areas that are slightly deeper, ranging from four to ten feet in pockets.

Other water uses – Pochet has relatively little boat traffic, primarily due to the shallow navigation channels.

Abutter interests/potential conflicts – The land surrounding Pochet is residential, and includes a private island. The site is also contained with the boundary of the Cape Cod National Seashore.

Acreage available within water bodies – Pochet Neck has a waterbody surface area of approximately 140 acres, but the area investigated for purposes of siting a FCW is approximately 17 acres.

Access points/easement requirements – Access to Pochet Neck would require a boat, and would have to occur during high tides.

Land ownership – The area is surrounded by privately owned residences. The site is located within the boundaries of the Cape Cod National Seashore, and a demonstration project would require the approval of the National Park Service. Per the public trust doctrine, the public has the right to certain uses (fish, fowling, navigation) between the mean low and mean high tide lines. Based on consultation with the Orleans Town Assessor, the land below the mean low tide line is likely owned by the Town of Orleans, although this should be confirmed through legal review.

(5) Quanset Pond is a small enclosed intertidal basin located in the southern reaches of Pleasant Bay. The 2006 MEP report estimates that existing nitrogen loads to Quanset Pond are 7.9 kg/day.

Water flow – Quanset Pond receives twice daily tidal inundation from the lower reaches of Pleasant Bay via a short channel. The Quanset Pond groundwater subbasin is located within the Pleasant Bay Basin, and flows northwest to southeast.

Bathymetry – Bathymetry data from NOAA indicates that the small pond is approximately three to seven feet in depth.

Other water uses – Quanset Pond has relatively few boat moorings and little boating activity.

Abutter interests/potential conflicts – The land surrounding Quanset Pond is largely residential.

Acreage available within water bodies – Quanset Pond's surface water area is approximately 7 acres in size.

Access points/easement requirements – Access to Quanset Pond is available via parking areas off of Quanset Road and Oyster Lane, and pathways around the pond. There is also a Town Landing located off of Quanset Road further off site, with eight spaces available for parking.

Land ownership – The land below the waters is held in Public Trust by the Town of Orleans. Private residences surround Quanset Pond and private ownership of the land extends to the low tide water line. Per the public trust doctrine, the public has the right to certain uses (fish, fowling, navigation) between the mean low and mean high tide lines. Based on consultation with the Orleans Town Assessor, the land below the mean low tide line is likely owned by the Town of Orleans, although this should be confirmed through legal review.

4. Enumerate Site Evaluation and Screening Criteria

To facilitate a systematic and objective evaluation of each of the potential demonstration sites, a site selection matrix was developed. The matrix includes a number of criteria obtained from the site conditions and observations to determine the overall site suitability for hosting a FCW demonstration project. The site selection criteria are defined below.

a. Site Evaluation and Screening Criteria

(1) Site Suitability Criteria

Use Conflicts: The FCW demonstration project will need to cover a certain percentage of surface water area such that the FCW is sizable enough to generate a measurable difference in water quality within the intertidal waterbody. The required percentage is not known but it is assumed that the minimum would be 10% coverage by the FCW project, as previous studies have determined that increased coverage leads to more effective nitrogen reduction rates (Winston 2012). This criterion rates whether or not there is enough open water surface area, given other uses of the waterbody, so that the FCW project will not impede other activities that occur at the site.

Utility Infrastructure Conflicts: The FCW demonstration project cannot impact or in any way impede on existing utility infrastructure. This criterion rates the potential impacts or conflicts a demonstration project might have with existing utility infrastructure.

Utility Infrastructure Benefits: The FCW demonstration project may benefit from the proximity of existing infrastructure. For example, the existence of a stormwater discharge pipe may provide a distinct source of nitrogen input to the system, allowing for more effective monitoring. Therefore, this criterion rates the potential benefits of existing utility infrastructure n proximity to a demonstration project.

Ease of Access: This criterion rates the ease with which demonstration site locations can be accessed for installation/construction, operation and maintenance.

Land Ownership: This criterion rates whether or not the ownership of the site will impede the project being accepted and implemented.

Depth of Surface Water: The deployment of the FCW typically requires only a six inch draft and so can be deployed in areas where mean low water is only one to two feet in depth. However, it is important that the water depth is never so low that the FCW impacts the benthic environment. It is also important that the water depth not be too great, so that water quality differences on the leeward and windward sides of the FCW are measurable, i.e. hydrologic mixing of the water is slowed due to the presence of the FCW. Therefore, this criterion rates the site based on presences of an optimal depth at mean low water from two to four feet.

Overall Likelihood of Monitoring Plan to Yield Quantified Results: To be able to measure water quality differences created by the installation of the FCW demonstration project, a site needs to be configured in a way that allows for some control of the hydrologic inputs and outputs of the site, which is challenging within a tidal waterbody characterized by complex hydrologic processes. This criterion rates the configuration of each site and likelihood that the demonstration project can be constructed in such a way that measurable results are able to be quantified.

Regulatory Criteria/Permitability: This criterion ranks the likelihood that the demonstration project will receive regulatory approval.

(2) Other Overriding Considerations

Additional considerations include the aesthetics of the FCW on the local surroundings and overall community buy in on the demonstration project. At this point in the review process, the information about the project and the potential site is not developed enough to include this criterion within the matrix. However, once a potential site is recommended, it will be fully vetted and aesthetic and community buy in must be considered.

5. Analysis: Evaluate and Rate Each Site based on Criteria

To rate each criterion in the Site Selection Matrix, the AECOM team collected available data, reviewed past reports and site maps, and conducted a site visit by land and by water. A rating system was then developed to quantify how well each site met a specific criterion. The point-based system is as follows:

- Good = 1 point: A good rating (1) was assigned if the criterion could be met fully.
- Neutral = 0 points: A neutral rating (0) was assigned if the criterion could be met in part, but there were some potential issues and/or difficulties
- Poor = -1 point: A poor rating (-1) was assigned if the criterion could not be met.

a. Weighting of Individual Criteria

It was determined by the team that no one criterion was most important than another, and therefore, each criterion was assigned equal weight.

b. Results of Each Site Rating

After the sites were rated for each criterion, an overall rating for each site was developed and sites were ranked in order of favorability. Results are presented in the following section.

6. Findings/Recommendations

The total rating and ranking of the sites is as follows::

- Recommended Site – Lonnie's Pond, 5 points
- Quanset Pond, 3 points
- Paw Wah Pond, 1 point
- Namequoit River, -1 point
- Pochet Neck, -1 point

These results were consistent with the overall assessment of the team after the field visits were completed, but before the site suitability matrix was developed and completed. The main reasons for Lonnie's Pond being ranked the highest for the potential site to implement the FCW demonstration project is due to the site's configuration including the narrow channel that outlets to the River, the existing stormwater pipe that discharges into the site, shallow depths in the area near the stormwater pipe, overall shallow depth of the pond, the ease of access to the site, and the lack of potential user conflict.

The other sites are all suitable for purposes of siting a FCW system; however, their site properties would make it relatively more difficult to monitor and measure the changes in water quality required for this demonstration project.

Quanset Pond and Paw Wah Pond are similar to Lonnie's Pond in many ways, but in general these two sites have a relatively smaller surface area. It is likely that, due to the other uses of the ponds, the FCW would also be relatively smaller than one placed in Lonnie's Pond, and therefore the resultant water quality changes would be more difficult to measure. In addition, the depth of Paw Wah Pond would make it more difficult to monitor changes as well.

Namequoit River and Pochet Neck are much more open systems, hydrologically, and would also present additional challenges when trying to measure water quality differences due to the placement of the FCW.

7. References

Dodkins, I and AF Mendzil. 2014. *Enterprise Assist: Floating Treatment Wetlands (FTWs) in water treatment: Treatment efficiency and potential benefits of activated carbon.* SEACAMS Swansea University. Prepared for FROG Environmental Ltd, Ban y Berlan, Llansadwrn, Llansadwrn, SA19 8 NA.

Massachusetts Estuaries Report: Linked Watershed-Embayment Approach to Determine Critical Nitrogen Loading Thresholds for the Nauset Harbor Embayment System Towns of Orleans and Eastham, Massachusetts (2012)

Massachusetts Estuaries Project Report: Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Pleasant Bay System, Orleans, Chatham, Brewster and Harwich, Massachusetts (MEP 2006)

National Oceanic and Atmospheric Administration: Nautical Chart for Chatham Harbor and Pleasant Bay. http://www.charts.noaa.gov/PDFs/13248.pdf (NOAA 2105)

Pleasant Bay Alliance Water Quality Monitoring Program: Statistical Analysis of 2000-2014 Water Quality Monitoring Data (Cadmus Group 2015)

Pleasant Bay Resource Management Alliance: Pleasant Bay Citizen Water Quality Monitoring Program Interim Report 2000-2008 (Alliance 2009)

Stantec. *Non-Traditional Technology Review Modify Orleans NT Bookends* – powerpoint presentation presented to the Orleans Water Quality Advisory Panel Meeting #4, October 2014.

Vymazal, J. (2007). Removal of nutrients in various types of constructed wetlands. *Science of the Total Environment*, vol. 380, no. 1-3, p. 48-65.

Winston, R. J., Hunt, W. F., & Kennedy, S. G. (2012). Evaluation of floating wetland islands as a retrofit to existing stormwater detention basins. In *World Environmental and Water Resources Congress 2012: Crossing Boundaries, Proceedings of the 2012 Congress.* (pp. 274-284). 10.1061/9780784412312.030

Criteria	Lonnie's Pond		Namequoit River		Paw Wah Pond		Pochet Neck		Quanset Pond	
	Rating	Score	Rating	Score	Rating	Score	Rating	Score	Rating	Score
Site Suitability										
Use Conflicts	1		0		0		0		1	
Utility/Infrastructure Conflicts	0		0		0		0		0	
Utility/Infrastructure Benefits	1		0		0		0		0	
Ease of Access	1		-1		1		-1		1	
Land Ownership	0		0		0		-1		0	
Depth of Surface Water	1		1		0		1		1	
Quantifiable Results	1		-1		0		0		0	
Regulatory Criteria	0		0		0		0		0	
Other/Overriding Considerations	N/A		N/A		N/A		N/A		N/A	
Total Criteria Points		**5**		**(1)**		**1**		**(1)**		**3**
Rank		**1**		**4**		**3**		**4**		**2**

Good = 1
Neutral = 0
Poor = -1

NON-TRADITIONAL TECHNOLOGY DESCRIPTIONS - SITING CRITERIA - LIMITATIONS AND CONSTRAINTS

BASELINE MEASURES

The DRAFT Cape Cod Area Wide Water Quality Management Plan Update (208 Plan) lists two main baseline measures that could be implemented in all watersheds, including:

- Non-structural source control measures such as fertilizer controls.
- Structural measures related to stormwater management best management practices (BMPs) promulgated through local regulations.
- Both stormwater and fertilizer remove sources of nitrogen from entering waterbodies.
- Timeframe for water quality improvements once implemented depend on distance to impaired waterbodies.

FERTILIZER MANAGEMENT

Technology Description, including information from the DRAFT Cape Cod Area Wide Water Quality Management Plan Update (208 Plan):

- Fertilizer load contributes 6% (1180 kg/year) of controllable nitrogen in Nauset Harbor watershed and 23% (8,135 kg/year) of the controllable load in Pleasant Bay watershed.
- Fertilizer controls are a source reduction strategy for this nitrogen source.
- 208 Plan recommends enforceable regulations and best management practices to reduce this load by 25%
- The cost of implementation is low.

The MEP model and a subsequent review of existing scientific literature and available data for the Massachusetts Department of Environmental Protection concluded that 20% leaching of applied fertilizer (used in the MEP models) was a reasonable rate for Cape Cod soil conditions (Horsley Witten Group Inc. 2009). A recent report prepared for the Cape Cod Commission, entitled "Cape Cod Pesticide and Fertilizer-Use Inventory" found that residential fertilizer use contributes the most to the fertilizer loading to groundwater on Cape Cod (Horsley Witten Group Inc. 2013). According to studies conducted by the golf course industry, leaching rates can be reduced to 10% or less using well-planned fertilization programs.

Best Management Practices (BMPs), education, and local fertilizer regulations will achieve nitrogen reduction. Effective enforcement is important. Unnecessary fertilizer applications are the component that leaches into groundwater. Prohibitions that remove these sources include:

- No fertilizer when grass is dormant
- No fertilizer on imperious surfaces (such as inadvertent application on driveways)
- No fertilizer before heavy rain events
- No over-fertilizing

Using slow-release instead of fast-release fertilizers, and appropriate watering and aerating can increase the health of turf and reduce the need for fertilizer. Transitioning to turf or other ground-cover that is less water and nitrogen-intensive is also useful. The concept of a "Cape-friendly Lawn" branding, and transitioning to other ground cover are seen as important goals for restoring impaired estuaries.

Performance

25% reduction in the nitrogen load (kilograms) attributable to the application of nitrogen from fertilizer.

Local Implementation

Orleans has an approved fertilizer control bylaw with enforceable regulations for the above BMPs. Moreover, this Bylaw prohibits any application of fertilizer within 100' of resource areas as defined by the Orleans Wetlands Regulations. Orleans has also drafted a phosphorus bylaw to accompany its grandfathered nitrogen bylaw, planned for fall 2014 Town Meeting approval. Enforcement through the Town Zoning Enforcement Officer (or designee) is likely to be complaints-driven, as is the case in many communities. This significant regulatory step would be enhanced by educational initiatives. There are a number of local organizations that may take the lead on public outreach and education. County-wide approaches may also be forthcoming.

Limitations and Constraints

- Awareness of and compliance with Bylaw

Next Steps

- Update Orleans Fertilizer Study to more accurately quantify the fertilizer nitrogen load.
- Identify groups that will lead or partner on educational initiatives.
- Notify property owners that are within 100' of resource areas about the bylaw.
    - Town of Falmouth has sent a letter from the Enforcement Officer that can be used as a template.
- Notify lawn service companies about the bylaw. Scott's Lawn has already contacted Falmouth stating that they are identifying all customers with lawns within the areas where nitrogen-application is prohibited to develop lawn management programs that do not use nitrogen fertilizer.
- From the mailing list, and Fertilizer Study Update, quantify the nitrogen-removal benefit of the prohibition against applying nitrogen fertilizer within 100' of resource areas.

<u>**STORMWATER MANAGEMENT**</u>

Technology Description, including information from the 208 Plan:

- Stormwater load contributes 9% (1770 kg/year) of controllable nitrogen in Nauset Harbor watershed and 13% (4,576 kg/year) in Pleasant Bay watershed.
- 208 Plan recommends Best Management Practices to reduce this load by 25%.
- Stormwater BMPs are a source reduction strategy for both nitrogen, and phosphorous.
- The cost of implementation is moderate when included as part of a larger public works project, and the nitrogen-removal benefits are rapid once the BMP is installed.

There are several stormwater treatment systems that can provide significant nutrient removal capabilities. Vegetated systems such as phytobuffers, constructed wetlands/gravel wetlands, vegetated swales, and bioretention systems are usually engineered to enhance the retention time of storm events. Physical filtration, uptake within plant tissue, nitrification-denitrification, and other microbial biochemical processes are engineered either alone or in series to optimize nutrient uptake and removal.

Phytobuffers, also known as vegetated filter strips are uniformly graded vegetated surfaces that receive runoff from adjacent impervious areas, and treat sheet flow or small concentrated flows that can be distributed along the width of the strip. These vegetated filter strips are designed to slow runoff velocities, trap sediment, promote infiltration, and biochemically metabolize pollutants. Water quality swales are vegetated open channels designed to treat water and convey runoff from a 10-year storm without causing erosion. They can be substituted for subsurface piping or open (unvegetated) channels to provide enhanced water quality treatment when constructed in association with other stormwater BMPs. Gravel or other constructed wetlands systems treat different categories of storm events, and are very effective at nutrient remediation because they include separate zones for aerobic (nitrification) and anoxic (denitrification) microbial activity. Depending on the system installed, it is estimated that stormwater BMPs remove 25% - 40% of nitrogen from impervious surfaces.

Performance

25% reduction in the nitrogen load (kilograms) attributable to the application of nitrogen from fertilizer.

Siting Criteria

- Space requirements vary by BMP.
- Orleans has conducted three major planning initiatives for stormwater management (an outfall inventory, an inlets and outfalls loading study, and a mapping initiative). These reports should be used to identify locations for installation of stormwater BMPs that have nitrogen-removal capacity.

Limitations and Constraints

- Life cycle costs
- Practical implementation (where to locate, size of catchment area, overall number of BMPs required to capture stormwater nitrogen and phosphorous loads)
- Actual nitrogen-removal rates given low starting concentrations in stormwater
- Maintenance and management

Pilot Projects on Cape Cod

The Environmental Protection Agency (EPA) has solicited proposals for stormwater BMPs on Cape Cod. Final project selection is expected before the end of 2014. Results of this EPA pilot and other studies should inform future implementation efforts.

INTENSIVE OYSTER AQUACULTURE, OYSTER REEFS, AND QUAHOG PROPAGATION

- Timeframe for water quality improvements (water clarity, nitrogen removal from water column) are within the first year of growth, once shellfish have been installed.
- This is a remediation technology.

Technology Description, including information from the DRAFT Cape Cod Area Wide Water Quality Management Plan Update (208 Plan):

Shellfish are biological filters, consuming the plankton that thrives on dissolved nitrogen and other nutrients in the water. By feeding, shellfish manage the concentration of plankton that continues to regenerate and grow as long as the water is warm. Plankton-removal improves water quality by both removing nitrogen and increasing water clarity. It has also been shown that the waste products of oysters in particular may augment denitrification of bottom sediments, thereby releasing nitrogen in the form of nitrogen gas to the atmosphere. Quahogs (Mercenaria mercenaria) benefit the benthos by hardening soft bottom sediments. According to the 208 Plan, co-benefits of oyster reefs may include habitat provision for juveniles and adults of commercially important fisheries as well as crustaceans (Coen et al. 2007), shoreline stabilization through reduced wave energy (Newell 2004), and increased removal of particulate matter, light penetration, and submerged aquatic vegetation growth, such as eelgrass, due to improvements in water clarity (Golden 2011). It is the synergistic ecologic benefits of nitrogen (and phosphorus) removal, water clarity improvements and improvement of bottom sediments that make shellfish cultivation an intriguing tool for estuaries restoration.

Shellfish aquaculture and reef restoration may also achieve economic and social benefits, in addition to meeting nutrient remediation and ecosystems restoration goals. Shellfish aquaculture and wild harvesting are established industries on Cape Cod, employing many growers and harvesters, and yielding a valuable end product. There are positive economic multipliers from local food production and jobs creation. Oysters are often the shellfish of choice because they are fast growing, and thus incorporate more nitrogen per growing season than other endemic shellfish. Moreover, growing techniques are well-understood and oysters have a relatively high market value. In Orleans, quahogs (Mercenaria mercenaria) are another important shellfish to consider because historically, quahogs have thrived here.

Performance

Cape Cod Cooperative Extension together with Woods Hole Sea Grant found that local Cape Cod oysters contain an average 0.28 grams of nitrogen per harvest size oyster (3 – 3.2", two years of growth). The nitrogen content of cultured off-bottom oysters was found to be slightly lower (0.26 grams/oyster). Mashpee reports 0.50 grams N per 3.5" oyster. Quahogs have slightly lower nitrogen content (0.22 grams of nitrogen per harvest size littleneck at 1" – 1.5", estimated four years of growth). Larger quahogs contain more nitrogen. Growing time for quahogs is twice that of oysters, and the market value is lower.

Oyster density is reported at 2,000,000 oysters per acre of reef in the Wellfleet restoration project. Falmouth's Little Pond Demonstration Project reports 1,250,000 oysters per acre for the first year of growth, with relay and bottom planting for the second year of growth at a density of approximately 1,000,000 oysters per acre. Commercial growers optimizing for a 2" oyster in one growing season have reported that they stock floating bags at lower densities (as low as 200 oysters per bag). Other growers stock at higher densities. The difference in nitrogen-removal is significant if oysters can be grown effectively at higher stocking densities. The range of densities presented in Table 1 is a function of the area being cultivated, the goals of the grower, and the growing method employed. Quahog densities presented in Table 2 are estimated by area and stocking density assumptions, and should be field-verified.

Table 1 and 2 incorporate research findings to date, for planning purposes. Denitrification rates are an important factor in calculating nitrogen-removal by oysters, and must be determined on a site-specific basis.

Table 1:

Planning Estimates for Oyster Nitrogen Removal - Shell and Soft Tissue Only

Size Class	# oysters per bag MAX	Nitrogen removal (g/oyster)	# bags per acre	# oysters per acre at max oysters per bag	N Removal per Acre @ max oysters per bag (kg)
1"	1500	0.008	1200	1,800,000	15
1.5"	1000	0.019	1200	1,200,000	22
2"	500	0.067	1200	600,000	40
3"	200	0.260	1200	240,000	62
3" (at avg N)	200	0.280	1200	240,000	67
3" (at avg N)	400	0.280	1200	480,000	134
3" (bottom/reef)	NA	0.500	NA	1,000,000	500
Denitrification					

Table 2:

Planning Estimates for Quahog (Mercenaria mercenaria) Nitrogen Removal - Shell and Soft Tissue Only

Size Class	# quahogs Planted	# quahogs harvested	Nitrogen removal (g/quahog)	N Removal per Acre (kg)
1" thick (Littlenecks)	1,000,000	800,000	0.08	64
2" thick (Quahogs)	1,000,000	800,000	0.24	192
4 years to grow				

Screening Criteria for Shellfish Propagation

- Biologically suitable areas for a range of growing methods:
  - Quahog growth in upwellers for eventual bottom propagation
  - Oyster off-bottom culture (individuals and spat-on-shell)
  - Oyster bottom culture (individuals and spat-on-shell)
  - Oyster Reefs
  - Coastal Habitat Restoration
- Suitable areas that do not conflict with current uses (boating) in terminal ponds and estuaries
- Suitable areas from a regulatory perspective
- Costs associated with management and logistics
  - Private versus public
  - Predation control
- Public acceptance (aesthetics of floating aquaculture equipment)
- Impact of climate change, rising water temperatures and ocean acidification on growth of shellfish, and future changes in predation and disease patterns

Key Permitting Authorities

- MassDEP – for TMDL-compliance credit
- USEPA – for TMDL-compliance credit
- Division of Marine and Fisheries (DMF)
- US Army Corps of Engineers through permit issued to the Commonwealth of Massachusetts (DMF)
- Board of Selectmen
- Harbormaster/ Shellfish Constable
- Department of Public Works (possible)
- Conservation Commission (possible)
- Pleasant Bay Area of Critical Environmental Concern may create other permitting requirements.

Next Steps - Quahogs:

To determine the feasibility of different shellfish scenarios in Orleans, the following are currently being reviewed:

- Current locations of quahogs (present/future)
- Current harvest of quahogs
- Carrying capacity (density) of quahogs per acre in Orleans
- Review results of propagation program in the 1990's (different terminal ponds were studied)
- Review operational needs

Next Steps - Oysters:

- Current nitrogen-removal benefits of Pleasant Bay Shellfish Grants
- Density (optimized) of oysters per acre growing in cages to harvest size in Orleans currently
- Denitrification rates under Grants
- Feasibility/acceptability/water quality benefits of "No Take" zones for spawn and nitrogen removal
- Feasibility/acceptability of harvested reefs for spawn and nitrogen removal
- Additional locations for oyster reefs, oyster aquaculture and quahog propagation
- Discuss Virginia Oyster Gardeners model for possible implementation in Orleans (terminal ponds/docks)
    - 300 oysters/bag x 3300 bags = ~1M oysters)

Limitations and Constraints

- Life cycle and monitoring costs
- Practical implementation (where to locate, size of growing area, risk management)
- Conflicting uses of water (boating, aesthetics) for gear-based operations
- Actual nitrogen-removal rates for different growing systems
- Maintenance and management – significant effort

Pilot Projects on Cape Cod

Wellfleet, Mashpee, and Falmouth are conducting pilot projects. The results of these projects have been incorporated into the planning estimates provided. Orleans has a number of active private growers with Shellfish Grants. The current and potential future production of these operations and their water quality benefits is under review.

<u>PERMEABLE REACTIVE BARRIERS – TRENCH METHOD, INJECTION WELL METHOD</u>

- Timeframe for water quality improvements (reduced nitrogen concentration of groundwater) could be within one year, but depends on the groundwater flow rate, residence time in the barrier, mobility of the treatment, distance of PRB from impaired waterbody, and other factors.
- PRBs are a source-reduction technology (nitrogen does not enter the waterbody).

Technology Description, including information from the DRAFT Cape Cod Area Wide Water Quality Management Plan Update (208 Plan):

A permeable reactive barrier (PRB) is a subsurface zone of reactive material designed to intercept and remediate contaminated groundwater. Utilizing different reactive media, PRBs have historically been used to treat groundwater contaminated by a broad range of contaminants including chlorinated solvents, arsenic, chromium, nitrate and other organic and inorganic compounds (US EPA 2012). Two types of PRB installations are discussed: trench and injection wells.

Trench PRBs

Trench PRBs designed for removal of nitrogen may be comprised of a media (such as wood chips or sawdust) that provides a readily biodegradable carbon source for use by denitryfing bacteria. Generally, trenches are constructed vertically, perpendicular to groundwater flow, in order to intersect and treat horizontally flowing groundwater. A funnel-and-gate configuration may also be used in conjunction with low-permeability materials to direct (funnel) groundwater towards a permeable treatment zone (gate). A trench-style PRB is typically excavated to a certain thickness and depth, determined by the desired treatment zone and the retention time. Then the trench is filled with a media (carbon source) that facilitates denitrification. The practical maximum depth that can be achieved with typical trenching equipment is 40 – 45 feet.

Injection Well PRBs

An injection well PRB is a network of wells by which a carbon source is injected in to the subsurface where it reacts with contaminated groundwater. There are a wide variety of carbon sources that have been used successfully in the field, such as emulsified vegetable oil (EVO), guar gum, fructose, corn syrup, molasses, methanol and ethanol. The injection wells are spaced to provide overlapping radii of influence (ROI) to create a continuous reactive zone. Spacing is determined on a site-specific basis and depends on site hydrogeology and design objectives. Radius of influence is usually a function of soil permeability. Glacial outwash and moraine areas often have variable permeability, depending on the amount of fine fraction in the soil. First order estimates for spacing of borings prepared for the Town of Falmouth suggest a distance of 20-25 feet apart, having a radius of influence of 12-15 feet from each injection point (PRB Technical Memorandum 5b). Injection wells installation methods are able to achieve maximum depths much greater than 40 – 45 feet.

Injection well technology is well-understood, having been used extensively to remove a wide range of contaminants from soils. At a recent workshop on PRBs sponsored by the Environmental Protection Agency, details regarding injection well technology were presented. Of note is that nitrogen species are routinely reduced, as this must occur before microbial activity acts on perchlorate.

Performance

Based on research conducted as part of the 208 Plan Update, the Cape Cod Commission's Technology Matrix provides removal rates for PRBs ranging from 70% to 99% of the nitrate in the groundwater that is intercepted. An extensive literature and regulatory technical review was recently conducted for the Town of Falmouth as part of its PRB Demonstration Project. Based on this work, the recommendation was made to assume 80% nitrogen-removal for planning purposes (PRB Technical Memorandum 5b, CDMSmith). Actual removal depends on the reducing conditions, and how much ammonia is generated and not adsorbed.

Downgradient impacts of PRBs (anaerobic byproducts such as methane, manganese, sulfide, and ferrous iron) may be generated by both trench and injection well PRBs. Understanding these interactions is a critical part of the evaluation process. Potential effects of the PRB to water quality such as increasing concentrations of iron and other constituents are reviewed as part of laboratory (bench) and field analysis prior to installing a PRB. When flow conditions and dosing requirements are well-understood, carbon sources have be injected for groundwater remediation in a way that does not result in surfacing or other downgradient impacts.

In terms of longevity, Trench PRBs have operated for over 10 years. A widely-recognized study conducted in Ontario, Canada showed that only 3% of the wood chip-based carbon source had been metabolized over a seven-year test period, suggesting that the longevity of this system could extend for decades (Robertson 2000). Injection well PRBs require rejuvenation, the frequency of which is best determined by a bench scale test, as well as a field scale pilot study.

To determine the mass or load of nitrogen that will be treated by a PRB installation, the groundwater capture zone must be determined. There are multiple methods to estimate and model the capture zone using water table/groundwater flow direction maps, groundwater flow and contaminant transport models, aquifer properties and analytical solutions. One method, the WatershedMVP planning tool, enables septic capture areas to be defined and nitrogen load reductions to be calculated. Evaluation tools will require field confirmation using site-specific data. Of note is that the WatershedMVP only includes septic load in its calculations, but a PRB also captures any upstream fertilizer and stormwater load that enters the groundwater.

Screening Criteria for PRB Installations

- Publicly-owned locations (roadways or public rights of way)
    - The Selection Criteria mapping tool developed as part of the 208 planning process shows a number of locations where depth to groundwater is less than 20’, including areas around terminal ponds, and along The River. However, these areas have private property down to the water’s edge. For planning purposes, it has been assumed that siting a PRB demonstration project in public locations is preferred.
- PRB location intersects a groundwater plume with high nitrogen concentrations (downstream of high density development, perpendicular to groundwater flow)
- Access for construction/ sites available up gradient and down gradient for monitoring
- As a secondary screen, review depth to groundwater to determine whether costs are impacted significantly by greater depths

General Installation Considerations

- Vertical thickness of the groundwater lens (thickness of the aquifer to reach saltwater interface)
    - Penetrating at least 20 feet of saturated aquifer thickness is desired, depending on groundwater flow rate
- Matching or exceeding the hydraulic conductivity and permeability of the surrounding groundwater matrix
- Extent of utility conflicts during installation (trench PRB)
- In general, the injection well PRB can be installed in areas with steeper topography than a trench PRB.
- In general, the injection well PRB can be installed in areas where utilities limit the installation of trench PRBs.

Key Permitting Authorities

- U.S. Army Corps of Engineers (USACE)
- USEPA
- MassEPA Unit
- MassDEP
- Massachusetts Division of Fisheries and Wildlife (DFW)
- Massachusetts Historic Commission (MHC)
- Cape Cod Commission
- Conservation Commission
- Planning and Zoning (earthmoving)
- Landowner permission if not a town road

Limitations and Constraints

- Life cycle and monitoring costs
- Practical implementation (where to locate, risk management)
- Actual nitrogen-removal rates
- Maintenance and management

Next steps for implementation of Modified 208 Plan Recommendation:

- Compile additional irrigation well data, if available
- Begin with bench scale tests and field investigations, to determine whether pursuing a Demonstration Project (less than 1000 linear feet) is worthwhile

Planning a Demonstration Project involves two main analytical steps, including (1) bench scale tests and (2) field (pilot) investigations. Bench scale tests are used to evaluate soil demand for a reducing agent, and groundwater chemistry such as dissolved oxygen, sulphate, pH, and other constituents, in addition to nitrate. Field investigations enable collection of data on soil types, stratigraphy, groundwater flow, hydraulic conductivity and other parameters. Fluorescent tracer tests can be conducted as part of initial field investigations to evaluate the radius of injections, and rate of carbon solution consumption (reinjection rates). The type of carbon source can also be optimized during both the bench scale and field investigations. The decision to employ injection wells versus trench PRBs will also be made after field investigations because this choice depends on depths, flow rates and potential for plugging. Based on these two analytical steps, the nitrogen-removal rates, as well as cost of installation, monitoring, operation and maintenance can be accurately estimated. Moreover, potential issues can be identified.

NOTE: 208 Plan recommendations for PRBs in Eastham (Salt Pond, Minister's Pond) have not been evaluated as part of the Orleans CWMP update.

Pilot Projects on Cape Cod

The Town of Falmouth completed a feasibility analysis for PRBs, with an extensive literature review and siting criteria. The screening criteria proposed above are based on the work in Falmouth, as well as additional research by the Cape Cod Commission. EPA Region 1 recommends piloting injection well and trench PRBs to determine their potential effectiveness for removing nitrogen loadings on Cape Cod.

FERTIGATION WELLS

- Timeframe for water quality improvements once implemented depend on travel time to impacted waterbody.
- Fertigation is a source reduction technology (reduces fertilizer use, plant uptake of nitrogen), with co-benefit of drinking water conservation

Technology Description, including information from the DRAFT Cape Cod Area Wide Water Quality Management Plan Update (208 Plan):

Fertigation refers to a system that uses irrigation wells to capture nitrogen-enriched groundwater and deliver it to plants for both watering and fertilization. By using reclaimed wastewater, a fertigation system captures the fertilizer benefit of nutrient-containing effluent in addition to conserving drinking water. Because turf takes up nitrogen, fertigation can significantly reduce nutrient loads to downgradient surface waters as well as reduce fertilizer costs and potable water use. High concentration groundwater is often found at the discharge sites of wastewater treatment facilities, sewage disposal areas, golf courses, areas of dense development with septic systems, and other facilities with large septic systems. Irrigated turf areas include golf courses, athletic fields and lawns.

Performance

The DRAFT Cape Cod Area Wide Water Quality Management Plan Update (p. 3-18) estimates that the nitrogen load reductions for turfgrass areas (such as golf courses, athletic fields or lawns) is 3.8 kg/acre-year. This planning estimate is based on a groundwater nitrogen concentration of 5 mg/L and water use records for managed golf course operations on Cape Cod. The mass of nutrients removed by fertigation is the product of the concentration of nitrogen in the groundwater, and the volume of water used. The reduction in nitrogen load of a fertigation system in Orleans would be calculated using actual water use data and fertilizer application records for the end user, as well as measured groundwater nitrogen concentrations.

Screening Criteria for Fertigation Wells

- Groundwater sources near areas where irrigation and fertilization occur
- Confirmed nitrogen concentration in groundwater at 5 mg/L minimum
- Fertilizer application rates that would be replaced by a fertigation system
- Monitoring of plant uptake of nitrogen, as opposed to reintroduction into groundwater

Key Stakeholders/Permitting Authorities for Fertigation Wells

- MassDEP
- USEPA
- Board of Health
- Conservation Commission
- Land Owner(s)
- Department of Public Works

Pilot Projects on Cape Cod

Case study from the 208 Plan:
The Pinehills golf course community in Plymouth installed a series of fertigation wells downgradient of the discharge site of its wastewater treatment plant. The pumped water is distributed to the golf course, reducing the amount of other fertilizer that is applied. During a two-year monitoring period an average of 434 kg N/year was reused. EPA Region 1 recommends piloting fertigation wells to determine this technology's potential effectiveness for removing nitrogen loadings on Cape Cod.

INNOVATIVE/ALTERNATIVE SEPTIC SYSTEMS

- Timeframe for water quality improvements once implemented depend on travel time to impacted waterbody.
- I/A Septic Systems are a source reduction technology

Technology Description, including information from the DRAFT Cape Cod Area Wide Water Quality Management Plan Update (208 Plan):

Single Unit Systems

Innovative and Alternative (I/A) septic systems collect and treat wastewater from individual dwellings, or commercial buildings and discharge it on the same lot. I/A systems are designed to remove more nitrogen than Title 5 septic systems and often include pumps, aerators, fans and other mechanical parts. Some I/A systems have provisions for chemical addition (pH adjustment and carbon source) increasing microbial denitrification in the unsaturated soils. There are numerous I/A system designs. However, there are only a few approved by MassDEP for the removal of nitrogen. When estimating nitrogen concentrations being discharged to groundwater, Title 5 systems are assumed to have a discharge concentration of 26.25 mg/L. This concentration includes all denitrification that occurs in the wastewater within the septic system and in the unsaturated soils as it reaches the water table. I/A systems achieve lower discharge nitrogen concentrations, but require a higher level of maintenance and are often more expensive to construct, operate and maintain than Title 5 septic systems. In terms of nitrogen-removal performance, I/A systems exhibit a range:

- Title 5 System – assumed discharge concentration of 26.25 mg/L
- Standard I/A System – Mass DEP approval to meet 19 mg/l effluent total nitrogen
- Enhanced I/A System – Mass DEP approval to meet 13 mg/l effluent total nitrogen
- Advanced I/A System – anticipated to routinely meet 5 - 12 mg/l effluent total nitrogen

Cluster I/A Systems

A single-stage cluster I/A system treats wastewater flows greater than 2,000 gallons per day. Subdivisions, apartments, condominiums, or businesses commonly employ cluster I/A systems. Nitrogen levels are typically treated to less than 15 mg/L. Two-stage cluster I/A systems also treat flows greater than 2,000 gallons per day, but include a separate denitrification stage. These systems may require chemical inputs, and an operator to monitor and run the system. Nitrogen levels are typically reduced to between 5 - 8 mg/L. Disinfection may be required as part of cluster I/A systems if the discharge is located within a Zone II of a public water supply well.

Screening Criteria for I/A Systems

- Lower density development
- Suitable hydrogeology
- Land area available
- Other permitting criteria can be met

Key Permitting Authorities for I/A Systems

- MA DEP – TMDL-credit
- Board of Health
- Pleasant Bay Area of Critical Environmental Concern may create other permitting requirements.
- For cluster I/A systems: other permitting authorities if system is part of a new construction project

Limitations and Constraints

- Reliable nitrogen-removal rates (tradeoff between cost and performance)
- Life cycle and monitoring costs
- Practical implementation (where to locate)

Pilot Projects on Cape Cod

The Alternative Septic System Test Center located at Joint Base Cape Cod is currently testing a number of I/A systems, including a non-proprietary "passive" design. In addition, the Test Center has an online database that lists the performance of every I/A system installed on Cape Cod. To use an I/A system not yet approved by MassDEP for nitrogen reduction, the system must go through an approval process. Proven, reliable nitrogen removal is a critical factor in the rating and approval process. Details of the I/A approval process, I/A system designs, and approved I/A systems are provided at the following MassDEP website: http://www.mass.gov/eea/agencies/massdep/water/wastewater/septic-systems-title-5.html#1 . In addition, the Town of Falmouth in collaboration with the Buzzards Bay Coalition has applied for a grant from to install at least 10 I/A Systems on shorefront homes in West Falmouth Harbor. Grant awards are expected in October.

ECO-TOILETS

- Timeframe for water quality improvements once implemented depend on the travel time to the impacted waterbody.
- Eco-Toilets are a source reduction technology

Technology Description, including information from the DRAFT Cape Cod Area Wide Water Quality Management Plan Update (208 Plan):

Eco-toilets separate human feces and urine from the wastewater system of a house or business. Once this source separation occurs, it is able to be composted on-site, or treated in a centralized facility. These human-derived components are then useable as a soil amendment that is rich in nutrients.
There are significant environmental advantages to such a system including:

- Eco-toilets divert the nitrogen that is in the feces and urine, so it does not enter groundwater. This decentralized approach replaces traditional wastewater management methods that are capital and resource intensive.
- Eco-toilets use minimal amounts of energy to operate, in most cases a 5-watt exhaust fan for venting is the only energy requirement.
- Water supply infrastructure and current plumbing paradigms first treat water to drinking water standards, then pipe it to homes where thousands of gallons per person per year are flushed down the toilet. This use of drinking water is wasteful of significant amounts of financial and energy resources. Eco-toilets replace this costly approach with technologies that do not use large amounts of drinking water to flush human excrement.
- Human feces and urine can be composted, or treated in other ways, and then used as fertilizers and soil conditioners that are rich in a wide variety of micro and macro nutrients. This conserves valuable natural resources, particularly phosphorus.

Eco-Toilet Technology Descriptions, including information from the 208 Plan

Eco-toilets include composting, urine diverting, incinerating, and packaging toilets and are typically coupled with a conventional system for gray water disposal systems (sinks, showers, baths, dishwashers, and washing machines). Composting toilets can either be self-contained, or have remote bins that hold the compost. Installation, operation, and maintenance manuals for each of the eco-toilets described below are available on the manufacturer's website. The energy use of the fans and heaters associated with each individual composting eco-toilet ranges from 120 to 540 watt-hours per day, or between 44 and 197 kilowatt-hours per year. Urine-diverting fixtures that discharge into a holding tank do not have any fans/heaters associated with them at present. However, the energy used to transport the stored urine should be considered. This will vary by distance.

Self-Contained Toilets

Self-contained toilets are not connected to household plumbing. These fixtures are easy to install, and are particularly useful in places where it is not feasible to connect the existing toilet to a central composting system. Such toilets are often found in basements, or where there is no space available for a central composting unit.

The following units have obtained Product Acceptance from the Massachusetts State Board of Plumbers and Gas Fitters and are approved alternative systems under 248 CMR 10.10:

- Envirolet/Santerra Green: A stand-alone composting toilet in which urine and feces are composted in the same built-in rotary composting unit. Compost is emptied by hand, typically at intervals of four to six months, depending on use. Various models are available. All Envirolet 120VAC electric models use a maximum of 540 watt-hours per day. 120VAC models have two 20W fans and one 500W heater. For more information, see www.envirolet.com .
- Sun Mar self-contained unit: A stand-alone composting toilet in which urine and feces are composted in the same built-in rotary composting unit (biochamber). Compost is emptied by hand, typically at intervals of four to six months, depending on use. Various models are available. Electricity use is 125 watts/day. (includes fan and heater, and assumes 50-percent operation) For more information, see www.sun-mar.com.
- BioLet: A stand-alone composting toilet in which urine and feces are composted in the same built-in rotary composting unit. Compost is emptied by hand at intervals. Various models are available. For more information, see www.biolet.com.

The following units require special permitting from the Massachusetts State Board of Plumbers and Gas Fitters.

- Separett: A stand-alone urine diverting toilet normally set up for hand disposal of both urine and feces that must/will be composted outside the home. The urine chamber of the Separett may also be connected to a large urine tank. For more information, see www.separett.com.
- EcoJohn incinerating toilets: These sewage waste combustion systems process both black and gray water. They are completely self-contained and operate without being connected to any septic or sewage systems. Energy requirements are significant. A small amount of sterile ash is produced. For more information, see http://ecojohn.com/index.html

The following unit can be used in conjunction with a composting system that has Product Acceptance.

Pacto Toilet: Urine and feces collected together in a sealed plastic sack that can be taken out of the toilet periodically and taken to a composting facility. Requires no electricity or bulking agent. For more information, see www.pacto.se, and Appendix 3-5.

Composting Toilet Systems with Remote Composting Bin(s)

Composting Toilet Systems with Remote Composting Bin(s) may consist of a central composting unit with either a single chamber, or a series of chambers filled consecutively. Multiple interchangeable composting units are also available. Composting systems can typically accommodate one or more toilet fixtures. Several different types of toilet fixture may be used. Waterless (dry) composting toilet fixtures as well as waterless (dry) urine-diverting fixtures are typically used when a bathroom toilet can be located directly above, or nearly above the composting unit. Human waste is moved by gravity through a 10- to 14-inch diameter pipe, from the toilet fixture into the composting unit. Foam flush, micro flush, and vacuum flush toilet fixtures can be used in locations that are not directly above the central composting unit. Some composting toilet systems require connection to a water supply.

The following units have obtained Product Acceptance from the Massachusetts State Board of Plumbers and Gas Fitters and are approved alternative systems under 248 CMR 10.10:

- Advanced Composting Systems (ACS)/Phoenix: Up to four toilets may be connected to a single composting container. Several types of toilet may be connected to the central composting container. Normally the toilet fixture will be a single chamber type with a wide opening through which both urine and feces are transferred to the composting container and processed into compost. A urine diverting dry toilet may also be used with a separate connection to a large urine storage tank. In difficult situations where a toilet is too far away from the composting container, a foam flush toilet may be used. A dedicated vent stack must be installed. The system requires a 5-watt fan that runs 24 hours/day = 120 watt-hours per day. For more information see www.compostingtoilet.com.
- Clivus Multrim: The manufacturer recommends that only single chamber toilets that transfer both urine and feces to the central processing unit be used. Clivus Multrim markets its own foam-flush toilet (Neptune) for situations where the toilet is too far away from the composting chamber for gravity discharge to the compost bin. A dedicated vent stack must be installed. The system requires a 5-watt fan that runs 24 hours/day = 120 watt-hours per day. For more information see www.clivusmultrum.com.
- Envirolet/Santerra Green Central Units: Both direct-discharge dry toilets, as well as vacuum flush units are available. Several toilets may be connected to a single composting container. A high capacity double tank is also available. FlushSmart™ VF™ is a vacuum flush and composting toilet system combination that is recommended for installations on rock or with little or no room below, basements, garages, workshops, pool cabanas, yurts, and applications where a smaller toilet is needed or desired. A dedicated vent stack must be installed. Central models use a maximum of 540W per day. A detailed description is provided in the technical description of the self-contained unit. For more information, see www.envirolet.com.
- Sun Mar Central Units: Several dry toilets may be connected to a single composting container. For locations where a direct gravity feed is not feasible, the manufacturer recommends use of a Sealand 510 or 511 marine toilets. This is an ultra-low flush toilet that may be installed either directly above or up to 15-feet away from the central composting unit. A dedicated vent stack must be installed. Electricity use is 125 watts/day (includes fan and heater, and assumes 50-percent operation).For more information, see www.sun-mar.com .
- Eco-Tech Carousel: Several types of composting toilets, including urine diverting dry toilets and foam flush toilets, may be connected to this set of bins in a rotating chamber. The urine diverting toilet will require connection to a large urine tank and the foam flush toilet must be connected to the household water line. There are two sizes of rotating chamber and each rotating chamber has four separate bins, only one of which is in use at a time. This system requires a 5-watt fan that runs 24 hours/day = 120 watt-hours per day. For more information, see www.ecological-engineering.com/carousel.html.

The following unit requires special permitting from the Massachusetts State Board of Plumbers and Gas Fitters.

- Full Circle: A 55 gallon wheelie bin is connected to a single dry composting fixture with urine-diversion. The bin collects feces for composting, with a separate storage container for urine. Each bin serves only one toilet. A dedicated vent stack must be installed for each bin. For more information, see www.fullcirclecompost.org.
- EcoJohn incinerating toilets: These sewage waste combustion systems process both black and gray water. They operate without being connected to any septic or sewage systems, and the incinerating unit can be located remotely (away from the toilet). Energy requirements are significant. A small amount of sterile ash is produced. For more information, see http://ecojohn.com/index.html

Summary of the Toilet Fixtures used with Composting Systems

Worldwide, many toilet fixtures are being produced for use with composting systems. Manufacturers specify which toilet fixtures are compatible with their composting systems.

- Dry composting toilets (with and without urine-diversion) are installed as part of a composting system. See manufacturer's recommendations for dry composting fixtures that are compatible.
- Ultra-low Flush Composting Toilets: The Sealand 510 and 511 models are the only examples mentioned, and they are recommended for use on Sun Mar central units where toilets must be offset from the central unit.

- Foam Flush Toilets: These function and look much like conventional toilets. Using a mix of biocompostable soap and water, the foam-flush moves waste through a 4-inch pipe to a composting tank below. The foam mixture cleans the toilet bowl with every flush but uses only about three ounces of water, making it fully compatible with the composting process. Since the foam flush is using water to carry the waste, toilets can be offset by up to 45-degrees from the composting bin. This facilitates installations where there is not space for a composting bin directly under a current fixture. These toilets are connected to a home's water supply.

- Vacuum Flush Toilets: The flushing action on these fixtures opens a valve in the toilet, enabling the contents of the toilet to be sucked with pressure, instead of gravity alone. There are a number of different types of vacuum toilets, ranging from toilets connected to vacuum sewer systems to toilets with a vacuum assist, which creates pressure to help flush the contents of a toilet with minimal water usage. Vacuum toilets are common on airplanes and are also used on boats and in personal homes. Because the vacuum involved can exert a substantial force, a vacuum toilet requires little to no water. Some use sanitizing liquids instead of water to keep the toilet relatively clean. Vacuum toilets are often very low-odor.

Urine-Diverting Flush Toilet Systems

Urine-diverting (UD) flush toilet systems connect to the household water and wastewater systems. Each toilet bowl has two chambers, one for feces and toilet paper and the other for urine. The urine chamber is connected to a large urine tank, the larger chamber to the household wastewater line. The following units have Test Site Status from the Massachusetts State Board of Plumbers and Gas Fitters for the demonstration. Up to 40 test sites have been authorized. The urine-diverting tanks are typically installed outside the home, and must be DEP-approved septic tanks with provision for pump-out and sealed against air intrusion. The entire UD system must be installed by a licensed plumber to ensure there is proper venting and traps. A key concern is to avoid blockages and odors from the urine line.

- Dubbletten "double flush" toilet: The urine and feces/toilet paper chambers flush separately, the urine chamber with very little water. The user need not flush the urine chamber after every use. To save water, it is recommended that paper used after urinating is disposed of in a separate receptacle near the toilet, and not flushed. For more information, see www.dubbletten.nu.

- Wostman Eco-Flush toilet: The urine and feces/toilet paper chambers flush separately, the urine chamber with very little water. The user need not flush the urine chamber after every use. To save water, it is recommended that paper used after urinating is disposed of in a separate receptacle near the toilet, and not flushed. For more information, see http://wostman.se/en/.
- Aquatron Centrifuge composting system: Wastewater from the feces/toilet paper chamber of one or more urine diverting toilets passes through a gravity-driven centrifuge that separates solid matter from wastewater going to the septic system. Solid matter drops out into a composting container. The Aquatron centrifuge may be used with any flush toilet, but for our demonstration it will be used with urine diverting flush toilets such as the Dubbletten or Wostmann toilets. For more information, see www.aquatron.se/index-2.php.
- Waterless (or very low flush urinals): There are many models that may be used in conjunction with UD toilets in any UD system. Any fixture that has Product Acceptance may be installed.

Urine Tanks Used with Urine-Diverting Toilets and Waterless or Ultra-Low Water Urinals
Any MassDEP-approved septic tank may be installed as part of the demonstration to hold urine. Tanks with a 500-gallon capacity are being used in the demonstration.

<u>Installation of Eco-Toilets</u>

In most cases, installing composting and urine diverting toilets in existing homes requires modifications to existing plumbing and venting. Space constraints are an important consideration, and sometimes bathroom remodeling is required. Building permits must be granted for these changes, and plumbing work must be code-compliant and be done by a licensed plumber. Any plumbing fixture installed in Massachusetts must have a Product Acceptance number. Several composting toilets have this approval. However, urine-diverting fixtures, source separators (such as Aquatron), and other pilot-stage urine-diverting and composting toilet technologies do not currently have a Product Acceptance number from the Massachusetts State Board of Plumbers and Gas Fitters (MSBPF), and are therefore illegal to install in the state. In order to install equipment that is not already approved, special permitting from the MSBPGF is required.

Selecting the best eco-toilet system is an iterative process involving the physical constraints of the built environment as well as cost and ongoing maintenance considerations. A site visit from someone capable of making these kinds of assessments is a critical component for many people, providing unbiased information on the full-range of eco-toilet configurations and the maintenance requirements that should be expected once an eco-toilet is installed. In addition, plumbers do not have a lot of experience installing these technologies. A Technical Coordinator to work with property owners, plumbers and regulators during the selection and installation process is necessary.

All eco- toilets require some form of residuals management. This is generally performed by a licensed septic hauler. Urine diverting toilets require the removal of urine from a holding tank. The compost and leachate from composting toilets requires periodic removal. Leachate is the excess liquid that is not taken up during process of composting. Leachate is very high in nitrogen and phosphorus; volumes produced range from <1 – 4 gallons/month/person. Incinerating toilets have a small ash residual requiring removal. Packaging toilets will also require frequent residuals removal.

The Town of Falmouth is conducting two demonstration projects related to eco-toilets to determine the nitrogen removal capabilities, cost, installation logistics, operations, and public acceptance of a broad range of composting and urine-diverting systems. Test Site status from the MBPGF for equipment that did not have Product Acceptance was obtained. Data from these Demonstration projects is still being collected. For planning purposes, a residential household which converts all toilets to approved eco-toilets will be removing nitrogen equivalent to an Enhanced or Advanced Innovative/Alternative septic system.

Limitations and Constraints

- Life cycle and monitoring costs
- Public acceptance
- Practical implementation (how to retrofit in homes with more than one bathroom)
- Handling of residuals (compost, leachate and urine)

Screening Criteria for Eco-Toilets

- User acceptance
- Title 5 septic system for grey water (sinks, dishwashers, showers, baths, laundry)
- Feasibility of retrofitting plumbing and making floor area modifications for eco-toilet based on site-specific conditions
- Plumbing board approval for desired technology
- Areas near freshwater ponds due to enhanced ability for phosphorus removal

Key Permitting Authorities for Eco-Toilets

- Board of Health
- Building Department
- State Board of Plumbers and Gas Fitters for Product Acceptance
- Pleasant Bay Area of Critical Environmental Concern may create other permitting requirements.
- MA DEP – TMDL-credit

Pilot Projects on Cape Cod

The Town of Falmouth has initiated two significant demonstration programs for eco-toilets. Results from the installation of the first 6 - 10 systems are expected by the end of 2014.

INLET WIDENING

- **Inlet widening is not being proposed as part of the Orleans Non-Traditional Bookend.**

The following technology description is included for completeness:

Technology Description, including information from the DRAFT Cape Cod Area Wide Water Quality Management Plan Update (208 Plan):

Inlet widening involves the re-engineering and reconstruction of a bridge or culvert opening to increase tidal flow. Maintenance dredging may also provide a similar function. According to several MEP Reports in which inlet widening is identified as a potentially beneficial measure, increasing tidal flux is expected to decrease the nitrogen residence time within the embayment or salt marsh, thereby lowering the nutrient concentrations. With the return of natural salinities, nutrient balance, and improved tidal exchange, and with opportunities for sediment to move more naturally through a coastal system, native plant and animal species may return and thrive.

Key benefits of inlet widening include:

- Provides passive treatment with minimal O&M
- Has numerous ecosystem benefits
- Nitrogen removal rate is dependent on many factors, including scope of restoration up to full tidal exchange

Screening Criteria for Inlet Widening

Preliminary feedback from Water Quality Advisory Panel, as well as the depth differential between the ponds and Pleasant Bay indicates that inlet dredging would not increase tidal prism. **Inlet widening is prohibited in the terminal ponds because they are part of the Pleasant Bay Area of Critical Environmental Concern (ACEC).**

- Waterbodies identified in MEP Reports as potentially beneficial (**none in Orleans watersheds under consideration**)
- Waterbodies identified by local stakeholders as constricted, and where the increased tidal volume would lead to an enhanced tidal prism and thus nitrogen removal.

Key Permitting Authorities for Inlet Widening

- Conservation Commission
- MassDEP – TMDL-credit
- MassDOT
- Division of Marine and Fisheries (DMF)
- Coastal Zone Management
- Natural Heritage
- US EPA – TMDL-credit
- US Army Corp of Engineers

Pilot Projects on Cape Cod

The Town of Falmouth is currently in the design and permitting phase of an inlet widening demonstration project for Bournes Pond. This project involves widening the current inlet from 50’ to 90’, with a new road and bridge, and is expected to remove over 50% of the nitrogen load entering this coastal pond. The permitting and monitoring framework is currently being established, and could serve as a valuable blueprint for other inlet widening initiatives on Cape Cod.

COASTAL HABITAT RESTORATION

- Timeframe for water quality improvements (water clarity, nitrogen removal from water column) once implemented are within the first year of full growth.
- Coastal Habitat Restoration is a remediation technology.

Restoration of coastal habitats includes establishing and/or enhancing estuary salt marshes, eel grass beds, and enhancing historic shellfish beds or reefs together as an ecosystem. The installation of riparian buffer zones and floating islands are also tools for restoring coastal habitats. The focus of restoration in the context of the Technology Matrix is on creating or rehabilitating native shellfish habitats. The 208 Plan includes reef restoration as a key component of Coastal Habitat Restoration. Nitrogen-removal is based on shellfish uptake.

Under the Department of Fish and Game, the Division of Ecological Restoration (DER) has developed inventories of some potential wetland restoration sites throughout Massachusetts. The purpose of these inventories is to identify, evaluate, and prioritize restoration opportunities that can be advanced by DER and others. The Cape Cod Atlas of Tidally Restricted Salt Marshes describes 7 sites in Orleans, 2 of which are shared.

However, the use of Coastal Habitat Restoration as a tool for nitrogen-removal is a somewhat different paradigm that the DER program, as currently articulated.

Siting Criteria for Coastal Habitat Restoration

- Navigable waters (shoreline reef systems do not interfere in the same way as aquaculture)
- Freshwater stream inflow
- Adequate flushing
- River systems with shoreline available
- Areas where shoreline erosion is occurring
- Aquaculture not allowed by regulation, or acceptable due to aesthetics

Key Permitting Authorities for Coastal Habitat Restoration

- Conservation Commission
- MassDEP/US EPA – TMDL-compliance credit
- Division of Ecological Restoration (DER)
- Division of Marine and Fisheries
- MassDOT
- Natural Heritage
- US Army Corps of Engineers
- US Fish and Wildlife Service
- Coastal Zone Management
- Landowners
- Pleasant Bay Area of Critical Environmental Concern may create other permitting requirements.

Local departments that may also be involved:

- Department of Public Works

Limitations and Constraints

- Life cycle and monitoring costs
- Practical implementation (specific locations that lend themselves to habitat restoration, risk management)
- Actual nitrogen-removal rates for different growing systems
- Maintenance and management

Pilot Projects on Cape Cod

- None for nutrient remediation: any demonstration site should be a self-contained small estuary where benthic as well as water quality conditions can be easily characterized and monitored

Next Step:

- Review terminal ponds and estuaries where coastal habitat restoration might be feasible and desirable.
- Planning for this approach should include consideration of the spectrum of shellfish growing options including propagation, aquaculture and reef programs to determine the best approach for different waterbodies.

FLOATING CONSTRUCTED WETLANDS

- Timeframe for water quality improvements (water clarity, nitrogen removal from water column) once implemented are within the first year of full growth.
- Floating Constructed Wetlands are a remediation technology.

Manmade floating "islands" act as floating wetlands that treat waters within ponds and estuaries. The islands are made of recycled materials that float on ponds or estuaries, exposing the plant's roots to the pond and estuarine waters. The root zones provide habitat for fish and microorganisms while reducing nitrogen and phosphorus levels. The floating islands can also be designed to allow shellfish and seaweed to grow which can be harvested, offsetting some of the systems costs. Some systems circulate surface water through the island, exposing the water to the root zones of the plants. The islands can be installed with shellfish beds and/or salt marsh grasses potentially assisting with their establishment. The islands are generally stationary and can be installed with walkways to access and maintain the plants growing on the islands. The islands require little O&M and do not need to be removed during the winter months, even if freezing water is a concern.

Siting Criteria for Floating Constructed Wetlands

- Navigable waters (reef systems do not interfere in the same way as aquaculture)
- Freshwater stream inflow
- Adequate flushing
- River systems with shoreline available
- Areas where shoreline erosion is occurring
- Aquaculture not allowed by regulation, or acceptable due to aesthetics

Key Permitting Authorities for Floating Constructed Wetlands

- Conservation Commission
- MassDEP/US EPA – TMDL-compliance credit
- US Army Corps of Engineers
- Division of Marine and Fisheries
- Pleasant Bay Area of Critical Environmental Concern may create other permitting requirements.

Local departments that may also be involved:

- Department of Public Works
- Harbormaster/Shellfish Dept.

Limitations and Constraints

- Life cycle and monitoring costs
- Practical implementation (specific locations, risk management)
- Conflicting uses of water (boating, navigation)
- Actual nitrogen-removal rates for different growing configurations
- Maintenance and management

Pilot Projects on Cape Cod

- Martha's Vineyard demonstration project, collaboration between Floating Islands International and Martha's Vineyard Shellfish Group, was installed mid- summer of 2014. Monitoring began, and will continue through (at minimum) summer, 2015. Four sites, with 2 – 4 wetlands systems per site are being evaluated.

The following research questions are being assessed:

- Will the BioHaven® matrix bio-foul from natural marine aquatic organisms or suspended detritus to a point where the matrix will not provide positive benefits in these marine environments at this scale?
- Does the matrix have any application for Geukensia demissa spat collection and/or culture?
- Does the periphyton that becomes attached to the matrix exhibit nitrification and/or denitrification potential? If so, to what extent?

LAND USE CONTROLS

- Timeframe for water quality improvements (water clarity, nitrogen removal from water column) once implemented depend on growth timeframes and groundwater travel times.
- Land Use Controls are a source reduction technology.

Land use planning is often implemented through zoning changes. Compact and open space development, transfer of development rights and overlay districts are three of several possible land use planning tools that are highlighted in the Technology Matrix. Purchase of land for open space and conservation restrictions also reduce future growth. Currently, Orleans has an average of ¾ acre zoning throughout town, with 6 units/acre maximum for apartments in certain areas.

Orleans Buildout Analysis

Summary of Findings

Existing level of development

Single family homes	3617
Condominium units	642
2-family home units	88
3-family home units	18
Other multi unit dwellings	104
Housing Authority	115
Apts. in Industrial District	22
Apts. in Business dists.	
Permitted accessory apartments	3
Total existing dwelling units	4,609

Potential Future Development

Vacant developable (undividable) building lots	528	
Potential new lots in Res. Districts		274
Potential new apts in business districts	412	
Potential new apts. in Industrial District	98	
Potential new apts. in the Village Center	290	
Total Potential Development		1,768

Current Density 2.05 residents per dwelling unit (US Census)

Siting Criteria for Land Use Changes

- Detailed build-out analysis based on "net useable land" has been completed by the Orleans Planning Department.
- Town Planner has confirmed that the findings are still valid.
- Findings incorporated into Comprehensive Wastewater Management Plan as "Practical Buildout"
- Land Use Controls should be pursued in the context of the Town's Local Comprehensive Plan

Key Approvals for Land Use Controls

- Planning Board
- Board of Selectmen
- Town Meeting

Local departments that will likely be involved:

- Planning Department

Limitations and constraints:

- Does not address current load
- Cannot stop all future load
- Public acceptance

SUMMARY OF 208 PLAN SCREENING LAYERS
Constructed Wetlands for Phyto-Technology
See 208 Screening Layers Map for exact locations

Locations include: Hopkins Island, parcel off White Pines Drive (wetlands), parcel off Route 6A at Boland Pond, and parcel off Indian Fort Hill Rd.

SUMMARY OF 208 PLAN SCREENING LAYERS
Constructed Wetlands for Groundwater Treatment
See 208 Screening Layers Map for exact locations

Rock Harbor:

- Constructed Wetlands for groundwater treatment - enhancement of existing wetlands system in two areas along creek
- Two parcels (wetlands) near Cedar Pond

Nauset Marsh – Town Cove:

- Constructed Wetlands for groundwater treatment – enhancement of existing wetlands at island E of Nauset Beach

Little Pleasant Bay:

- Constructed Wetlands for groundwater treatment – enhancement of existing wetlands east of Archer Lane, west of Sparrowhawk Rd along Bay, at Barley Neck (point) , Tar Kiln Road, Simpson Meadow island

Namskaket

- Constructed Wetlands for groundwater treatment - enhancement of existing wetlands system on several parcels

SUMMARY OF 208 PLAN SCREENING LAYERS
Constructed Wetlands for Wastewater Treatment
See 208 Screening Layers Map for exact locations

Rock Harbor:

- Constructed Wetlands for wastewater at Defiance Lane

Nauset Marsh – Town Cove:

- Constructed Wetlands for watestwater - several sites, to be reviewed as part of wastewater discharge planning

Little Pleasant Bay:

- Constructed Wetlands - several sites, to be reviewed as part of wastewater discharge planning

Namskaket

- Constructed Wetlands for wastewater at Boas Drive, off Salty Ridge Rod

Areys Pond Subwatershed
Hybrid #3 Evaluation Tool

Arey's Pond Statistics:
(Orleans only)
Total acreage = 13 acres
Total Number of Parcels = 67
Total Wastewater Flow (MVP) = ~7,400
Total Nitrogen Load (kg from MVP) = 269

		Number of Lots Sewered or Area/Quantities of NT Technologies	Flow (GPD)	Nutrient Removal Certainty: Nitrogen (Saltwater) Phosphorus (Freshwater)		Implementation Certainty*		Other Benefits: Ecosystems, Economic, Social		Adaptability to Uncertainty in Nutrient-Reduction Goals and Buildout		CEC removal: Yes = 1 No = 0	Non-Quantitative Factors Total Score	Cost
				Score	Description	Score	Description	Score	Description	Score	Description	Score		
MEP Goal Reduction for Total Watershed (kg/year)	#REF!													
Nitrogen Removal Method	**kg/year Removed**													
Fertilizer (25% of MEP att)	6													
Stormwater	0													
PRB														
Floating Constructed Wetlands														
Aquaculture	136	**0.5M oysters, ~ 1 acre floating bags;**	NA	**3**	**N uptake in shell and soft tissue is well-documented**	**2**	**oysters already growing (upweller); main risks: catastrophic event causing die-off, mismanagement**	**3**	**rapid N removal, filtering for water clarity, denitrification, product has revenue potential and can create local economic activity, scalable**	**3**	**scalable, rapid test of load reduction goal**	**0**	**11**	**$$**
Coastal Habitat Restoration														
Eco-Toilets														
UD Eco-Toilets														
I/A Septic Systems														
Sewers	0													
Sub-Total Removed =	142													
Total Remaining =	#REF!													

KEY
1 = LOW
2 = MEDIUM
3 = HIGH
Higher scores indicate more positive attributes

DISCLAIMERS: These numbers and cost scores are planning level estimates. The scores for non-quantitative factors are starting points for discussion.

KEY (Cost/kg-N Removed: 20-Yr Present Worth Capital and O&M&M)
$ = $0 - $5,000
$$ = $5,000 - $10,000
$$$ = $10,000 - $15,000
$$$$ = $15,000 - $20,000
$$$$$ = $20,000 - $40,000

Alternate Technologies

Floating Constructed Wetlands	150	**400 sf to 11,500 sf, cost based on 3/4 of MAX (8700 sf)**	NA	**1**	**actual N removal per sf needs field verification**	**2**	**many examples of successful installations. main risks: actual size required, permitting uncertainty and mismanagement**	**3**	**creates complex habitat, filtering for water clarity, rapid water quality improvements, attractive**	**3**	**scalable, rapid test of load reduction goal**	**0**	**9**	**$ - $$**

Kescayo Ganset (Lonnies) Pond Subwatershed
Hybrid #3 Evaluation Tool

Kescayo Ganset (Lonnies) Pond Statistics:
(Orleans only)
Total acreage = 16 acres
Total Number of Parcels = 131
Total Wastewater Flow (MVP) = ~11,000
Total Nitrogen Load (kg from MVP) = 360

		Number of Lots Sewered or Area/Quantities of NT Technologies	Flow (GPD)	Nutrient Removal Certainty: Nitrogen (Saltwater) Phosphorus (Freshwater)		Implementation Certainty*		Other Benefits: Ecosystems, Economic, Social		Adaptability to Uncertainty in Nutrient-Reduction Goals and Buildout		CEC removal: Yes = 1 No = 0	Non-Quantitative Factors Total Score	Cost
				Score	Description	Score	Description	Score	Description	Score	Description	Score		
MEP Goal Reduction for Total Watershed (kg/year)	#REF!													
Nitrogen Removal Method	**kg/year Removed**													
Fertilizer (25% of MEP att)	8													
Stormwater	0	credit once BMP is quantified												
PRB	150	700 feet, Herring Brook Way (56 properties)	NA	3	N-removal well-documented, local verification needed	2	site characterization needed for final determination on feasibility, unintended downstream chemistry	2	rapid water quality improvements, captures all present and future upstream N load to groundwater	3	scalable, rapid test of load reduction goal	1	11	$$ - $$$
Floating Constructed Wetlands	150	400 sf to 11,500 sf, cost based on 3/4 of MAX (8700 sf)	NA	1	actual N removal per sf needs field verification	2	many examples of successful installations. main risks: actual size required, permitting uncertainty and mismanagement	3	creates complex habitat, filtering for water clarity, rapid water quality improvements, attractive	3	scalable, rapid test of load reduction goal	0	9	$$
Aquaculture														
Coastal Habitat Restoration														
Eco-Toilets														
UD Eco-Toilets														
I/A Septic Systems														
Sewers	0													
Sub-Total Removed =	308													
Total Remaining =	#REF!													

KEY
1 = LOW
2 = MEDIUM
3 = HIGH
Higher scores indicate more positive attributes

DISCLAIMERS: These numbers and cost scores are planning level estimates. The scores for non-quantitative factors are starting points for discussion.

KEY (Cost/kg-N Removed: 20-Yr Present Worth Capital and O&M&M)
$ = $0 - $5,000
$$ = $5,000 - $10,000
$$$ = $10,000 - $15,000
$$$$ = $15,000 - $20,000
$$$$$ = $20,000 - $40,000

Alternate Technologies

Aquaculture/CHR	290	~ 1 acre reef with remote set and trays; 1M oysters or quahogs	NA	3	N uptake in shell and soft tissue is well-documented	1	remote set in trays proven method to minimize predation, need field verification; main risks: catastrophic event causing die-off, mismanagement	3	rapid N removal, filtering for water clarity, denitrification and other reef habitat, less economic benefit than aquaculture, scalable	3	scalable, rapid test of load reduction goal	0	10	$
Floating Constructed Wetlands	290	750 sf to 23,000 sf, cost based on 3/4 of MAX (17000 sf)	NA	1	actual N removal per sf needs field verification	2	many examples of successful installations, minimal management needs. main risks: actual size required, permitting uncertainty robustness over time	3	creates complex habitat, filtering for water clarity, rapid water quality improvements, attractive	3	scalable, rapid test of load reduction goal	0	9	$ - $$

Meetinghouse Pond Subwatershed
Hybrid #3 Evalutaion Tool

Meetinghouse Pond Statistics: (Orleans only)
Total acreage = 45 acres
Total Number of Parcels = 338
Total Wastewater Flow (MVP) = ~44,000
Total Nitrogen Load (kg from MVP) = 1876

Nitrogen Removal Method	kg/year Removed	Number of Lots Sewered or Area/Quantities of NT Technologies	Flow (GPD)	Nutrient Removal Certainty: Nitrogen (Saltwater) Phosphorus (Freshwater) Score	Description	Implementation Certainty* Score	Description	Other Benefits: Ecosystems, Economic, Social Score	Description	Adaptability to Uncertainty in Nutrient-Reduction Goals and Buildout Score	Description	CEC removal: Yes = 1 No = 0 Score	Non-Quantitative Factors Total Score	Cost
MEP Goal Reduction for Total Watershed (kg/year)	#REF!													
Fertilizer (25% of MEP att)	35													
Stormwater	0													
PRB														
Floating Constructed Wetlands														
Aquaculture														
Coastal Habitat Restoration	150	~ 0.5 acre reef with remote set and trays; ~0.5 M oysters	NA	3	N uptake in shell and soft tissue is well-documented	2	remote set in trays proven method to minimize predation and maximize oysters per unit area, need field verification of viability; main risks: catastropic event causing die-off, mismanagement	3	rapid N removal, filtering for water clarity, denitrification and other reef habitat, less economic benefit than aquaculture	3	allows higher density areas to be sewered, scalable	0	11	$-$$
Eco-Toilets														
UD Eco-Toilets														
I/A Septic Systems														
Sewers	1742	310	40455	3		3		3	addresses sanitary needs, supports economic centers	3	areas of uncertainty can be delayed to future phases, scalable	1	13	$$$

Sub-Total Removed = 1927
Total Remaining = #REF!

KEY
1 = LOW
2 = MEDIUM
3 = HIGH
Higher scores indicate more positive attributes

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KEY (Cost/kg-N Removed: 20-Yr Present Worth Capital and O&M&M)
$ = $0 - $5,000
$$ = $5,000 - $10,000
$$$ = $10,000 - $15,000
$$$$ = $15,000 - $20,000
$$$$$ = $20,000 - $40,000

Alternate Technologies

Nitrogen Removal Method	kg/year Removed	Number of Lots Sewered or Area/Quantities of NT Technologies	Flow (GPD)	Nutrient Removal Certainty Score	Description	Implementation Certainty* Score	Description	Other Benefits Score	Description	Adaptability Score	Description	CEC removal Score	Non-Quantitative Factors Total Score	Cost
PRB (overlaps sewer area)	260	1500 feet, Loomis Lane (78 properties)	NA	3	N-removal well-documented, local verification needed	1	significant uncertainty regarding gw flow in this watershed. site characterization needed for final determination on feasibility, unintended downstream chemistry	2	rapid water quality improvements, captures all present and future upstream N load to groundwater	3	scalable, rapid test of load reduction goal	1	10	$$ - $$$
Floating Constructed Wetland	150	400 sf to 11,500 sf, cost based on 3/4 of MAX (8700 sf)	NA	1	actual N removal per sf needs field verification	2	many examples of successful installations, minimal management needs. main risks: actual size required, permitting unceratinty robustness over time	3	creates complex habitat, filtering for water clarity, rapid water quality improvements, attractive	3	scalable, rapid test of load reduction goal	0	9	$ - $$
Innovative/Alternative Septic Systems	1749	583	NA	3	Permitting and Monitoring	2	a few advanced systems available for single family installations, requires maintanance and management	2	addresses sanitary needs, supports economic centers	3	can install in more homes	0	10	$$$$

Namequoit River Subwatershed
Hybrid #3 Evalutaion Tool

Namequoit River Statistics (Orleans only):
Total acreage = 44 acres
Total Number of Parcels = 209
Total Wastewater Flow (MVP)= ~23,000
Total Nitrogen Load (kg from MVP) = 716

		Number of Lots Sewered or Area/Quantities of NT Technologies	Flow (GPD)	Nutrient Removal Certainty: Nitrogen (Saltwater) Phosphorus (Freshwater)		Implementation Certainty*		Other Benefits: Ecosystems, Economic, Social		Adaptability to Uncertainty in Nutrient-Reduction Goals and Buildout		CEC removal: Yes = 1 No = 0	Non-Quantitative Factors Total Score	Cost
				Score	Description	Score	Description	Score	Description	Score	Description	Score		
MEP Goal Reduction for Total Watershed (kg/year)	#REF!													
Nitrogen Removal Method	**kg/year Removed**													
Fertilizer (25% of MEP att)	15													
Stormwater	0													
PRB														
Floating Constructed Wetlands	350	875 sf to 27,000 sf, cost based on 3/4 of MAX (20,000)	NA	1	actual N removal per sf needs field verification	2	many examples of successful installations, minimal management needs. main risks: actual size required, permitting unceratinty robustness over time	3	creates complex habitat, filtering for water clarity, rapid water quality improvements, attractive	3	scalable, rapid test of load reduction goal	0	9	$-$$
Aquaculture														
Coastal Habitat Restoration														
Eco-Toilets														
UD Eco-Toilets														
I/A Septic Systems														
Sewers	0													
Sub-Total Removed =	365													
Total Remaining =	#REF!													

KEY
1 = LOW
2 = MEDIUM
3 = HIGH
Higher scores indicate more positive attributes

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KEY (Cost/kg-N Removed: 20-Yr Present Worth Capital and O&M&M)
$ = $0 - $5,000
$$ = $5,000 - $10,000
$$$ = $10,000 - $15,000
$$$$ = $15,000 - $20,000
$$$$$ = $20,000 - $40,000

Alternate Technologies

Coastal Habitat Restoration	350	~ 1.5 acre reef with remote set and trays; 1.5 M oysters or quahogs	NA	3	N uptake in shell and soft tissue is well-documented	2	remote set in trays proven method to minimize predation and maximize oysters per unit area, need field verification of viability; main risks: catastropic event causing die-off, mismanagement	3	rapid N removal, filtering for water clarity, denitrification and other reef habitat, less economic benefit than aquaculture, scalable	3	scalable, rapid test of load reduction goal	0	11	$
PRB	200	2000 feet, Namequoit Rd (70 properties)	NA	3	N-removal well-documented, local verification needed	2	site characterization needed for final determination on feasibility, unintended downstream chemistry	2	rapid water quality improvements, captures all present and future upstream N load to groundwater	3	scalable, rapid test of load reduction goal	1	11	$$ - $$$

Paw Wah Subwatershed
Hybrid #3 Evalutaion Tool

Paw Wah Statistics (Orleans only):
Total acreage = 6 acres
Total Number of Parcels = 127
Total Wastewater Flow (MVP)= ~14,700
Total Nitrogen Load (kg from MVP) = 534

		Number of Lots Sewered or Area/Quantities of NT Technologies	Flow (GPD)	Nutrient Removal Certainty: Nitrogen (Saltwater) Phosphorus (Freshwater)		Implementation Certainty*		Other Benefits: Ecosystems, Economic, Social		Adaptability to Uncertainty in Nutrient-Reduction Goals and Buildout		CEC removal: Yes = 1 No = 0	Non-Quantitative Factors Total Score	Cost
				Score	Description	Score	Description	Score	Description	Score	Description	Score		
MEP Goal Reduction for Total Watershed (kg/year)	#REF!													
Nitrogen Removal Method	**kg/year Removed**													
Fertilizer (25% of MEP att)	11													
Stormwater	0													
PRB	323	1200 feet, Lockwood Lane (87 properties)	NA	3	N-removal well-documented, local verification needed	2	site characterization needed for final determination on feasibility, unintended downstream chemistry	2	rapid water quality improvements, captures all present and future upstream N load to groundwater	3	scalable, rapid test of load reduction goal	1	11	$$
Floating Constructed Wetlands														
Aquaculture														
Coastal Habitat Restoration	80	~ 0.33 acre oyster reef or 0.3M quahogs	NA	3	N uptake in shell and soft tissue is well-documented	2	remote set in trays proven method to minimize predation and maximize oysters per unit area, need field verification of viability; main risks: catastropic event causing die-off, mismanagement	3	rapid N removal, filtering for water clarity, denitrification and other reef habitat, less economic benefit than aquaculture	3	scalable, rapid test of load reduction goal	0	11	$$
Eco-Toilets														
UD Eco-Toilets														
I/A Septic Systems														
Sewers	0													
Sub-Total Removed =	414													
Total Remaining =	#REF!													

KEY
1 = LOW
2 = MEDIUM
3 = HIGH
Higher scores indicate more positive attributes

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KEY (Cost/kg-N Removed: 20-Yr Present Worth Capital and O&M&M)
$ = $0 - $5,000
$$ = $5,000 - $10,000
$$$ = $10,000 - $15,000
$$$$ = $15,000 - $20,000
$$$$$ = $20,000 - $40,000

Alternate Technologies

Floating Constructed Wetlands	320	800 sf to 25,000 sf, cost based on 3/4 of MAX (18,000 sf)	NA	1	actual N removal per sf needs field verification	2	many examples of successful installations, minimal management needs. main risks: actual size required, permitting unceratinty robustness over time	3	creates complex habitat, filtering for water clarity, rapid water quality improvements, attractive	3	scalable, rapid test of load reduction goal	0	9	$ - $$

Pochet Neck Subwatershed
Hybrid #3 Evalutaion Tool

Pochet Neck Statistics (Orleans only):
Total acreage = 140 acres
Total Number of Parcels = 551
Total Wastewater Flow (MVP) = ~62,000
Total Nitrogen Load (kg from MVP) = 2,211

		Number of Lots Sewered or Area/Quantities of NT Technologies	Flow (GPD)	Nutrient Removal Certainty: Nitrogen (Saltwater) Phosphorus (Freshwater)		Implementation Certainty*		Other Benefits: Ecosystems, Economic, Social		Adaptability to Uncertainty in Nutrient-Reduction Goals and Buildout		CEC removal: Yes = 1 No = 0	Non-Quantitative Factors Total Score	Cost
				Score	Description	Score	Description	Score	Description	Score	Description	Score		
MEP Goal Reduction for Total Watershed (kg/year)	0													
Nitrogen Removal Method	**kg/year Removed**													
Fertilizer (25% of MEP att)	60													
Stormwater	0													
PRB														
Floating Constructed Wetlands	730	1800 sf to 56,000 sf, cost based on 3/4 of MAX (42,000 sf)	NA	1	actual N removal per sf needs field verification	1	many examples of successful installations, minimal management needs. main risks: actual size required, permitting unceratinty robustness over time	3	creates complex habitat, filtering for water clarity, rapid water quality improvements, attractive	3	scalable, rapid test of load reduction goal	0	8	$
Aquaculture														
Coastal Habitat Restoration	780	~ 3 acre reef with remote set and trays initially, may lead to reef without trays; 2M oysters or quahogs (bottom planted)	NA	3	N uptake in shell and soft tissue is well-documented	2	remote set in trays proven method to minimize predation and maximize oysters per unit area, need field verification of viability; main risks: catastropic event causing die-off, mismanagement	3	rapid N removal, filtering for water clarity, denitrification and other reef habitat, less economic benefit than aquaculture	3	scalable, rapid test of load reduction goal	0	11	$
Eco-Toilets														
UD Eco-Toilets														
I/A Septic Systems														
Sewers	0													
Sub-Total Removed =	1570													
Total Remaining =	-1570													

KEY
1 = LOW
2 = MEDIUM
3 = HIGH
Higher scores indicate more positive attributes

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KEY (Cost/kg-N Removed: 20-Yr Present Worth Capital and O&M&M)
$ = $0 - $5,000
$$ = $5,000 - $10,000
$$$ = $10,000 - $15,000
$$$$ = $15,000 - $20,000
$$$$$ = $20,000 - $40,000

Alternate Technologies

PRB	238	1500', Briar Spring Road (77 properties)	NA	3	N-removal well-documented, local verification needed	2	site characterization needed for final determination on feasibility, unintended downstream chemistry	2	rapid water quality improvements, captures all present and future upstream N load to groundwater	3	scalable, rapid test of load reduction goal	1	11	$$$
Floating Constructed Wetlands	370	900 sf to 29,000 sf, cost based on 3/4 of MAX (21,000)	NA	1	actual N removal per sf needs field verification	1	many examples of successful installations. main risks: actual size required, permitting uncertainty and mismanagement	3	creates complex habitat, filtering for water clarity, rapid water quality improvements, attractive	3	scalable, rapid test of load reduction goal	0	8	$-$$
Coastal Habitat Restoration	260	~ 1 acre reef with remote set and trays initially; 1M oysters or quahogs	NA	3	N uptake in shell and soft tissue is well-documented	2	remote set in trays proven method to minimize predation, need field verification; main risks: catastrophic event causing die-off, mismanagement	3	rapid N removal, filtering for water clarity, denitrification and other reef habitat, less economic benefit than aquaculture	3	scalable, rapid test of load reduction goal	0	11	$$

Quanset Subwatershed
Hybrid #3 Evaluation Tool

Quanset Statistics (Orleans Only):
Total acreage = 13 acres
Total Number of Parcels = 50
Total Wastewater Flow (MVP) = ~7,400
Total Nitrogen Load (kg from MVP) = 268

		Number of Lots Sewered or Area/Quantities of NT Technologies	Flow (GPD)	Nutrient Removal Certainty: Nitrogen (Saltwater) Phosphorus (Freshwater)		Implementation Certainty*		Other Benefits: Ecosystems, Economic, Social		Adaptability to Uncertainty in Nutrient-Reduction Goals and Buildout		CEC removal: Yes = 1 No = 0	Non-Quantitative Factors Total Score	Cost
				Score	Description	Score	Description	Score	Description	Score	Description	Score		
MEP Goal Reduction for Total Watershed (kg/year)	#REF!													
Nitrogen Removal Method	**kg/year Removed**													
Fertilizer (25% of MEP att)	6													
Stormwater	0													
PRB														
Floating Constructed Wetlands	250	**625 sf to 19,200 sf, cost based on 3/4 of MAX (15,000)**	NA	**1**	**actual N removal per sf needs field verification**	**1**	**many examples of successful installations, minimal management needs. main risks: actual size required, permitting uncertainty robustness over time**	**3**	**creates complex habitat, filtering for water clarity, rapid water quality improvements, attractive**	**3**	**scalable, rapid test of load reduction goal**	**0**	**8**	**$-$$**
Aquaculture														
Coastal Habitat Restoration														
Eco-Toilets														
UD Eco-Toilets														
I/A Septic Systems														
Sewers	0													
Sub-Total Removed =	256													
Total Remaining =	#REF!													

KEY
1 = LOW
2 = MEDIUM
3 = HIGH
Higher scores indicate more positive attributes

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KEY (Cost/kg-N Removed: 20-Yr Present Worth Capital and O&M&M)
$ = 0 - $5,000
$$ = $5,000 - $10,000
$$$ = $10,000 - $15,000
$$$$ = $15,000 - $20,000
$$$$$ = $20,000 - $40,000

DEMO site for FCW should run MEP model to plan demo and understand its water quality impacts relative to mixing in entire watershed

Alternate Technologies

Coastal Habitat Restoration	250	**~ 1 acre reef with remote set and trays initially, may lead to reef without trays**	NA	**3**	**N uptake in shell and soft tissue is well-documented**	**2**	**remote set in trays proven method to minimize predation and maximize oysters per unit area, need field verification of viability; main risks: catastrophic event causing die-off, mismanagement**	**3**	**rapid N removal, filtering for water clarity, denitrification and other reef habitat, less economic benefit than aquaculture, scalable**	**3**	**scalable, rapid test of load reduction goal**	**0**	**11**	**$**

The River Upper Subwatershed
Hybrid #3 Evaluation Tool

The River Upper Statistics:
(Orleans only)
Total acreage = 22 acres
Total Number of Parcels = 200
Total Wastewater Flow (MVP) = ~21,000
Total Nitrogen Load (kg from MVP) = 664

		Number of Lots Sewered or Area/Quantities of NT Technologies	Flow (GPD)	Nutrient Removal Certainty: Nitrogen (Saltwater) Phosphorus (Freshwater)		Implementation Certainty*		Other Benefits: Ecosystems, Economic, Social		Adaptability to Uncertainty in Nutrient-Reduction Goals and Buildout		CEC removal: Yes = 1 No = 0	Non-Quantitative Factors Total Score	Cost
				Score	Description	Score	Description	Score	Description	Score	Description	Score		
MEP Goal Reduction for Total Watershed (kg/year)	#REF!													
Nitrogen Removal Method	**kg/year Removed**													
Fertilizer (25% of MEP att)	16													
Stormwater	0													
PRB														
Floating Constructed Wetlands	175	400 sf to 13,000 sf, cost based on 3/4 of MAX (10,000)	NA	1	actual N removal per sf needs field verification	1	many examples of successful installations, minimal management needs. main risks: actual size required, permitting uncertainty robustness over time	3	creates complex habitat, filtering for water clarity, rapid water quality improvements, attractive	3	scalable, rapid test of load reduction goal	0	8	$-$$
Aquaculture														
Coastal Habitat Restoration	0													
Eco-Toilets														
UD Eco-Toilets														
I/A Septic Systems														
Sewers	173	47	4765	3		3		3	addresses sanitary needs, supports economic centers	3	areas of uncertainty can be delayed to future phases, scalable	1	13	$$$
Sub-Total Removed =	364													
Total Remaining =	#REF!													

KEY
1 = LOW
2 = MEDIUM
3 = HIGH
Higher scores indicate more positive attributes

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KEY (Cost/kg-N Removed: 20-Yr Present Worth Capital and O&M&M)
$ = 0 - $5,000
$$ = $5,000 - $10,000
$$$ = $10,000 - $15,000
$$$$ = $15,000 - $20,000
$$$$$ = $20,000 - $40,000

Alternate Technologies

Aquaculture	175	0.75M oysters, ~ 2 acre floating bags;	NA	3	N uptake in shell and soft tissue is well-documented	2	field test of viability needed. main risks: catastrophic event causing die-off, mismanagement	3	rapid N removal, filtering for water clarity, denitrification, product has revenue potential and can create local economic activity, scalable	3	scalable, rapid test of load reduction goal	0	11	$$
Coastal Habitat Restoration	175	~ 3/4 acre reef with remote set and trays; .75M oysters or quahogs	NA	3	N uptake in shell and soft tissue is well-documented	2	remote set in trays proven method to minimize predation and maximize oysters per unit area, need field verification of viability; main risks: catastrophic event causing die-off, mismanagement	3	rapid N removal, filtering for water clarity, denitrification and other reef habitat, less economic benefit than aquaculture, scalable	3	scalable, rapid test of load reduction goal	0	11	$$

The River Lower Subwatershed
Hybrid #3 Evaluation Tool

The River Lower Statistics:
(Orleans only)
Total acreage = 177 acres
Total Number of Parcels = 226
Total Wastewater Flow (MVP) = ~25,000
Total Nitrogen Load (kg from MVP) = 907

		Number of Lots Sewered or Area/Quantities of NT Technologies	Flow (GPD)	Nutrient Removal Certainty: Nitrogen (Saltwater) Phosphorus (Freshwater)		Implementation Certainty*		Other Benefits: Ecosystems, Economic, Social		Adaptability to Uncertainty in Nutrient-Reduction Goals and Buildout		CEC removal: Yes = 1 No = 0	Non-Quantitative Factors Total Score	Cost
				Score	Description	Score	Description	Score	Description	Score	Description	Score		
MEP Goal Reduction for Total Watershed (kg/year)	#REF!													
Nitrogen Removal Method	**kg/year Removed**													
Fertilizer (25% of MEP att)	23													
Stormwater	0													
PRB														
Floating Constructed Wetlands														
Aquaculture														
Coastal Habitat Restoration	530	~ 2 acre reef with remote set and trays initially; 2M oysters or quahogs (which would be bottom planted)	NA	3	N uptake in shell and soft tissue is well-documented	2	remote set in trays proven method to minimize predation and maximize oysters per unit area, need field verification of viability; main risks: catastrophic event causing die-off, mismanagement	3	rapid N removal, filtering for water clarity, denitrification and other reef habitat, less economic benefit than aquaculture	3	scalable, rapid test of load reduction goal	0	11	$
Eco-Toilets														
UD Eco-Toilets														
I/A Septic Systems														
Sewers	0													
Sub-Total Removed =	553													
Total Remaining =	#REF!													

KEY
1 = LOW
2 = MEDIUM
3 = HIGH
Higher scores indicate more positive attributes

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KEY (Cost/kg-N Removed: 20-Yr Present Worth Capital and O&M&M)
$ = 0 - $5,000
$$ = $5,000 - $10,000
$$$ = $10,000 - $15,000
$$$$ = $15,000 - $20,000
$$$$$ = $20,000 - $40,000

Alternate Technologies

Floating Constructed Wetlands	530	1300 sf to 41,000 sf, cost based on 3/4 of MAX (31,000 sf)	NA	1	actual N removal per sf needs field verification	1	many examples of successful installations, minimal management needs. main risks: actual size required, permitting uncertainty robustness over time	3	creates complex habitat, filtering for water clarity, rapid water quality improvements, attractive	3	scalable, rapid test of load reduction goal	0	8	$-$$

Pleasant Bay Subwatershed
Hybrid #3 Evaluation Tool

Pleasant Bay Main Basin Statistics: (Orleans only)
Total acreage = 3,300 acres
Total Number of Parcels = 638
Total Wastewater Flow (MVP) = ~71,500
Total N Load (kg from MVP) = 2,325

		Number of Lots Sewered or Area/Quantities of NT Technologies	Flow (GPD)	Nutrient Removal Certainty: Nitrogen (Saltwater) Phosphorus (Freshwater)		Implementation Certainty*		Other Benefits: Ecosystems, Economic, Social		Adaptability to Uncertainty in Nutrient-Reduction Goals and Buildout		CEC removal: Yes = 1 No = 0	Non-Quantitative Factors Total Score	Cost
				Score	Description	Score	Description	Score	Description	Score	Description	Score		
MEP Goal Reduction for Total Watershed (kg/year)	#REF!													
Nitrogen Removal Method	**kg/year Removed**													
Fertilizer (25% of MEP att)	751													
Stormwater	0													
PRB														
Floating Constructed Wetlands	440	**1100 sf to 34,000 sf, cost based on 3/4 of MAX (25,000 sf)**	NA	**1**	**actual N removal per sf needs field verification**	**1**	**many examples of successful installations, minimal management needs. main risks:**	**3**	**creates complex habitat, filtering for water clarity, rapid water quality improvements, attractive**	**3**	**scalable, rapid test of load reduction goal**	**0**	**8**	**$**
Aquaculture	620	**Program to ensure that ~2.5 M oysters or quahogs are grown within existing grants annually**	NA	**3**	**N uptake in shell and soft tissue is well-documented**	**2**	**oysters already growing (grants); main risks: catastrophic event causing die-off, industry cooperation**	**3**	**rapid N removal, filtering for water clarity, denitrification, product has revenue potential and can create local economic activity**	**3**	**scalable, rapid test of load reduction goal**	**0**	**11**	**$**
Coastal Habitat Restoration	420	**~ 2 acre reef with remote set and trays initially, may lead to reef without trays; 2M oysters or quahogs (bottom planted)**	NA	**3**	**N uptake in shell and soft tissue is well-documented**	**2**	**remote set in trays proven method to minimize predation and maximize oysters per unit area, need field verification of viability; main risks: catastropic event causing die-off, mismanagement**	**3**	**rapid N removal, filtering for water clarity, denitrification and other reef habitat, less economic benefit than aquaculture**	**3**	**scalable, rapid test of load reduction goal**	**0**	**11**	**$**
Eco-Toilets														
UD Eco-Toilets														
I/A Septic Systems														
Removal by Other Town(s)	#REF!													
Sewers	0													
Sub-Total Removed =	#REF!													
Total Remaining =	#REF!													

KEY
1 = LOW
2 = MEDIUM
3 = HIGH
Higher scores indicate more positive attributes

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KEY (Cost/kg-N Removed: 20-Yr Present Worth Capital and O&M&M)
$ = 0 - $5,000
$$ = $5,000 - $10,000
$$$ = $10,000 - $15,000
$$$$ = $15,000 - $20,000
$$$$$ = $20,000 - $40,000

Alternate Technologies

Innovative/Alternative Septic Systems	868	**289**	NA	**3**	**Permitting and Monitoring**	**2**	**a few advanced systems available for single family installations, requires maintanance and management**	**2**	**addresses sanitary needs, supports economic centers**	**3**	**can install in more homes**	**0**	**10**	**$$$$**

Town Cove Subwatershed
Hybrid #3 Evaluation Tool

Town Cove Statistics:
(Orleans only)
Total acreage = 390 acres
Total Number of Parcels = 1024
Total Wastewater Flow (MVP) = ~155,000
Total Nitrogen Load (kg from MVP) = 5550

		Number of Lots Sewered or Area/Quantities of NT Technologies	Flow (GPD)	Nutrient Removal Certainty: Nitrogen (Saltwater) Phosphorus (Freshwater)		Implementation Certainty*		Other Benefits: Ecosystems, Economic, Social		Adaptability to Uncertainty in Nutrient-Reduction Goals and Buildout		CEC removal: Yes = 1 No = 0	Non-Quantitative Factors Total Score	Cost
				Score	Description	Score	Description	Score	Description	Score	Description	Score		
MEP Goal Reduction for Total Watershed (kg/year)	#REF!													
Nitrogen Removal Method	**kg/year Removed**													
Fertilizer (25% of MEP att)	126													
Stormwater	0													
PRB	856	2200 feet, Main St/Tonset (~221 properties)	NA	3	N-removal well-documented, local verification needed	2	site characterization needed for final determination on feasibility, unintended downstream chemistry	2	rapid water quality improvements, captures all present and future upstream N load to groundwater	3	scalable, rapid test of load reduction goal	1	11	$
Floating Constructed Wetlands	600	1500 sf to 46,000 sf, cost based on 3/4 of MAX (35,000)	NA	1	actual N removal per sf needs field verification	1	many examples of successful installations, minimal management needs. main risks: actual size required, permitting uncertainty robustness over time	3	creates complex habitat, filtering for water clarity, rapid water quality improvements, attractive	3	scalable, rapid test of load reduction goal	0	8	$-$$
Aquaculture	600	~ 2.5 acre reef/remote set with trays and/or mix with quahogs; 3M oysters or quahogs total	NA	3	N uptake in shell and soft tissue is well-documented	2	remote set in trays proven method to minimize predation, need field verification; main risks: catastrophic event causing die-off, mismanagement	3	rapid N removal, filtering for water clarity, denitrification and other reef habitat, less economic benefit than aquaculture	3	scalable, rapid test of load reduction goal	0	11	$
Coastal Habitat Restoration	500	~ 2 acre reef with remote set and trays initially; 1M oysters or quahogs	NA	3	N uptake in shell and soft tissue is well-documented	2	remote set in trays proven method to minimize predation, need field verification; main risks: catastrophic event causing die-off, mismanagement	3	rapid N removal, filtering for water clarity, denitrification and other reef habitat, less economic benefit than aquaculture	3	scalable, rapid test of load reduction goal	0	11	$$
Eco-Toilets														
UD Eco-Toilets														
I/A Septic Systems														
Removal by Other Town(s)	#REF!													
Sewers	#REF!	194	59,303	3		3		3	addresses sanitary needs, supports economic centers	3	areas of uncertainty can be delayed to future phases, scalable	1	13	$$
Sub-Total Removed =	#REF!													
Total Remaining =	#REF!													

KEY
1 = LOW
2 = MEDIUM
3 = HIGH
Higher scores indicate more positive attributes

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KEY (Cost/kg-N Removed: 20-Yr Present Worth Capital and O&M&M)
$ = $0 - $5,000
$$ = $5,000 - $10,000
$$$ = $10,000 - $15,000
$$$$ = $15,000 - $20,000
$$$$$ = $20,000 - $40,000

Alternate Technologies

Floating Constructed Wetlands	105	250 sf to 7,700 sf, cost based on 3/4 of MAX (5800 sf)	NA	1	actual N removal per sf needs field verification	2	many examples of successful installations. main risks: actual size required, permitting uncertainty and mismanagement	3	creates complex habitat, filtering for water clarity, rapid water quality improvements, attractive	3	scalable, rapid test of load reduction goal	0	9	$$
Innovative/Alternative Septic Systems	3226	1075	NA	3	Permitting and Monitoring	2	a few advanced systems available for single family installations, requires maintanance and management	2	addresses sanitary needs, supports economic centers	3	can install in more homes	0	10	$$$$
PRB	0	3600 feet, Gibson Road (~250 properties)	NA	3	N-removal well-documented, local verification needed	2	site characterization needed for final determination on feasibility, unintended downstream chemistry	2	rapid water quality improvements, captures all present and future upstream N load to groundwater	3	scalable, rapid test of load reduction goal	1	11	$$

Mill Pond Subwatershed
Hybrid #3 Evaluation Tool

Mill Pond Statistics:
(Orleans only)
Total acreage = 81 acres
Total Number of Parcels = 318
Total Wastewater Flow (MVP) = ~35,000
Total Nitrogen Load (kg from MVP) = 1,278

		Number of Lots Sewered or Area/Quantities of NT Technologies	Flow (GPD)	Nutrient Removal Certainty: Nitrogen (Saltwater) Phosphorus (Freshwater)		Implementation Certainty*		Other Benefits: Ecosystems, Economic, Social		Adaptability to Uncertainty in Nutrient-Reduction Goals and Buildout		CEC removal: Yes = 1 No = 0	Non-Quantitative Factors Total Score	Cost
				Score	Description	Score	Description	Score	Description	Score	Description	Score		
MEP Goal Reduction for Total Watershed (kg/year)	626													
Nitrogen Removal Method	**kg/year Removed**													
Fertilizer (25% of MEP att)	34													
Stormwater	0													
PRB														
Floating Constructed Wetlands	370	900 sf to 29,000 sf, cost based on 3/4 of MAX (21,000)	NA	1	actual N removal per sf needs field verification	1	many examples of successful installations. main risks: actual size required, permitting uncertainty and mismanagement	3	creates complex habitat, filtering for water clarity, rapid water quality improvements, attractive	3	scalable, rapid test of load reduction goal	0	8	$-$$
Aquaculture														
Coastal Habitat Restoration	260	~ 1 acre reef with remote set and trays initially; 1M oysters or quahogs	NA	3	N uptake in shell and soft tissue is well-documented	2	remote set in trays proven method to minimize predation, need field verification; main risks: catastrophic event causing die-off, mismanagement	3	rapid N removal, filtering for water clarity, denitrification and other reef habitat, less economic benefit than aquaculture	3	scalable, rapid test of load reduction goal	0	11	$$
Eco-Toilets														
UD Eco-Toilets														
I/A Septic Systems														
Removal by Other Town(s)	0													
Sewers	#REF!													
Sub-Total Removed =	#REF!													
Total Remaining =	#REF!													

KEY
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3 = HIGH
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KEY (Cost/kg-N Removed: 20-Yr Present Worth Capital and O&M&M)
$ = 0 - $5,000
$$ = $5,000 - $10,000
$$$ = $10,000 - $15,000
$$$$ = $15,000 - $20,000
$$$$$ = $20,000 - $40,000

Alternate Technologies

PRB	285	2000 feet, Brick Hill Road (87 properties)	NA	3	N-removal well-documented, local verification needed	2	site characterization needed for final determination on feasibility, unintended downstream chemistry	2	rapid water quality improvements, captures all present and future upstream N load to groundwater	3	scalable, rapid test of load reduction goal	1	11	$$$

Rock Harbor Subwatershed
Hybrid #3 Evaluation Tool

Rock Harbor Statistics:
(Orleans only)
Total acreage = 5 acres
Total Number of Parcels = 334
Total Wastewater Flow (MVP) = ~65,500
Total Nitrogen Load (kg from MVP) = 1,855

Nitrogen Removal Method	kg/year Removed	Number of Lots Sewered or Area/Quantities of NT Technologies	Flow (GPD)	Nutrient Removal Certainty: Nitrogen (Saltwater) Phosphorus (Freshwater) Score	Nutrient Removal Certainty Description	Implementation Certainty* Score	Implementation Certainty* Description	Other Benefits: Ecosystems, Economic, Social Score	Other Benefits Description	Adaptability to Uncertainty in Nutrient-Reduction Goals and Buildout Score	Adaptability Description	CEC removal: Yes = 1 No = 0 Score	Non-Quantitative Factors Total Score	Cost
MEP Goal Reduction for Total Watershed (kg/year)	#REF!													
Fertilizer (25% of MEP att)	46													
Stormwater	0													
PRB - either RHR or Captain's Row, etc.	634	2100 feet, Upper RHR, Captain's Row, mid RHR (114 properties MIN)	NA	3	N-removal well-documented, local verification needed	2	site characterization needed for final determination on feasibility, unintended downstream chemistry	2	rapid water quality improvements, captures all present and future upstream N load to groundwater	3	scalable, rapid test of load reduction goal	1	11	$$
Floating Constructed Wetlands (enhanced)	250	625 sf to 19,200 sf, cost based on 3/4 of MAX (15,000)	NA	1	actual N removal per sf needs field verification	1	many examples of successful installations, minimal management needs. main risks: actual size required, permitting uncertainty robustness over time	3	creates complex habitat, filtering for water clarity, rapid water quality improvements, attractive	3	scalable, rapid test of load reduction goal	0	8	$-$$
Aquaculture														
Coastal Habitat Restoration														
Eco-Toilets														
UD Eco-Toilets														
I/A Septic Systems	0													
Removal by Other Town(s)	#REF!													
Sewers	#REF!	23	12735	3		3		3	addresses sanitary needs, supports economic centers	3	areas of uncertainty can be delayed to future phases, scalable	1	13	$
Sub-Total Removed =	#REF!													
Total Remaining =	#REF!													

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KEY (Cost/kg-N Removed: 20-Yr Present Worth Capital and O&M&M)
$ = $0 - $5,000
$$ = $5,000 - $10,000
$$$ = $10,000 - $15,000
$$$$ = $15,000 - $20,000
$$$$$ = $20,000 - $40,000

Alternate Technologies

Sewer mid section 473
NO room for Aquaculture
NO efficacious PRB location

Nitrogen Removal Method	kg/year Removed	Number of Lots Sewered or Area/Quantities of NT Technologies	Flow (GPD)	Nutrient Removal Certainty Score	Nutrient Removal Certainty Description	Implementation Certainty* Score	Implementation Certainty* Description	Other Benefits Score	Other Benefits Description	Adaptability Score	Adaptability Description	CEC removal Score	Non-Quantitative Factors Total Score	Cost
PRB - Route 6 to avoid RHR, sewer area omitted	391	2100 feet, Route 6 (89 properties)	NA	3	N-removal well-documented, local verification needed	2	site characterization needed for final determination on feasibility, unintended downstream chemistry	2	rapid water quality improvements, captures all present and future upstream N load to groundwater	3	scalable, rapid test of load reduction goal	1	11	$$
Innovative/Alternative Septic Systems	1270	423	NA	3	Permitting and Monitoring	2	a few advanced systems available for single family installations, requires maintanance and management	2	addresses sanitary needs, supports economic centers	3	can install in more homes	0	10	$$$$
PRB -all Rock Harbor Rd.	1040	5280 feet, Rock Harbor Road (243 properties)	NA	3	N-removal well-documented, local verification needed	2	site characterization needed for final determination on feasibility, unintended downstream chemistry	2	rapid water quality improvements, captures all present and future upstream N load to groundwater	3	scalable, rapid test of load reduction goal	1	11	$$
PRB - less of Rock Harbor Rd.	889	2200 feet, Rock Harbor Road smaller (137 properties)	NA	3	N-removal well-documented, local verification needed	2	site characterization needed for final determination on feasibility, unintended downstream chemistry	2	rapid water quality improvements, captures all present and future upstream N load to groundwater	3	scalable, rapid test of load reduction goal	1	11	$$

Rock Harbor Subwatershed
Hybrid #3 Evaluation Tool

Cedar Pond Statistics:
(Orleans only)
Total acreage = 16 acres
Total Number of Parcels = 78
Total Wastewater Flow (MVP) = ~17,200
Total Nitrogen Load (kg from MVP) = 625

		Number of Lots Sewered or Area/Quantities of NT Technologies	Flow (GPD)	Nutrient Removal Certainty: Nitrogen (Saltwater) Phosphorus (Freshwater)		Implementation Certainty*		Other Benefits: Ecosystems, Economic, Social		Adaptability to Uncertainty in Nutrient-Reduction Goals and Buildout		CEC removal: Yes = 1 No = 0	Non-Quantitative Factors Total Score	Cost
				Score	Description	Score	Description	Score	Description	Score	Description	Score		
MEP Goal Reduction for Total Watershed (kg/year)	0													
Nitrogen Removal Method	**kg/year Removed**													
Fertilizer (25% of MEP att)	2													
Stormwater	0													
PRB - Cedar Pond	165	2600 feet, Locust Road (60 properties)	NA	3	N-removal well-documented, local verification needed	2	site characterization needed for final determination on feasibility, unintended downstream chemistry	2	rapid water quality improvements, captures all present and future upstream N load to groundwater	3	scalable, rapid test of load reduction goal	1	11	$$$$$
PRB - less of Rock Harbor Rd.	0													
Floating Constructed Wetlands	0													
Aquaculture														
Coastal Habitat Restoration														
Eco-Toilets														
UD Eco-Toilets														
I/A Septic Systems	0													
Removal by Other Town(s)	0													
Sewers	151	44	12822	3		3		3	addresses sanitary needs, supports economic centers	3	areas of uncertainty can be delayed to future phases, scalable	1	13	$$$$
Sub-Total Removed =	318													
Total Remaining =	-318													

KEY
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$ = $0 - $5,000
$$ = $5,000 - $10,000
$$$ = $10,000 - $15,000
$$$$ = $15,000 - $20,000
$$$$$ = $20,000 - $40,000

Rock Harbor Subwatershed
Hybrid #3 Evaluation Tool

Little Namskaket Statistics:
Total acreage = 3 acres
Total Number of Parcels = 285
Total Wastewater Flow (MVP) = ~63,350
Total Nitrogen Load (kg from MVP) = 1998

		Number of Lots Sewered or Area/Quantities of NT Technologies	Flow (GPD)	Nutrient Removal Certainty: Nitrogen (Saltwater) Phosphorus (Freshwater)		Implementation Certainty*		Other Benefits: Ecosystems, Economic, Social		Adaptability to Uncertainty in Nutrient-Reduction Goals and Buildout		CEC removal: Yes = 1 No = 0	Non-Quantitative Factors Total Score	Cost
				Score	Description	Score	Description	Score	Description	Score	Description	Score		
MEP Goal Reduction for Total Watershed (kg/year)	-1835													
Nitrogen Removal Method	**kg/year Removed**													
Fertilizer (25% of MEP att)	35													
Stormwater	0													
PRB - Cedar Pond														
PRB - less of Rock Harbor Rd.														
Floating Constructed Wetlands														
Aquaculture														
Coastal Habitat Restoration														
Eco-Toilets														
UD Eco-Toilets														
I/A Septic Systems														
Removal by Other Town(s)	0													
Sewers	457	**21**	**12591**	**3**		**3**		**3**	**addresses sanitary needs, supports economic centers**	**3**	**areas of uncertainty can be delayed to future phases, scalable**	**1**	**13**	**$**
Sub-Total Removed =	492													
Total Remaining =	-2327													

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$$ = $5,000 - $10,000
$$$ = $10,000 - $15,000
$$$$ = $15,000 - $20,000
$$$$$ = $20,000 - $40,000