AECOM
9 Jonathan Bourne Drive
Pocasset, MA 02559
www.aecom.com

508.833.6950 tel
508.833.6951 fax

Memorandum

To	George Meservey, Director of Planning & Community Development Michael Domenica, PE, Program Manager
CC	Betsy Shreve, AICP, AECOM Project Director Terry Doss, Biohabitats Inc. Pete Munoz, Biohabitats Inc. Jennifer Doyle-Breen, AECOM Paula Winchell, AECOM
Subject	**Town of Orleans, MA** **Water Quality and Wastewater Planning** **Task Number 3 – Non Traditional Demonstration Projects** **Deliverable 3.a.1 - Final Technical Memorandum for Site Characterization and Evaluation for Floating Constructed Wetlands**
Project Number	60476644
From	Thomas Parece, P.E., AECOM Project Manager
Date	May 25, 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; and
- 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).

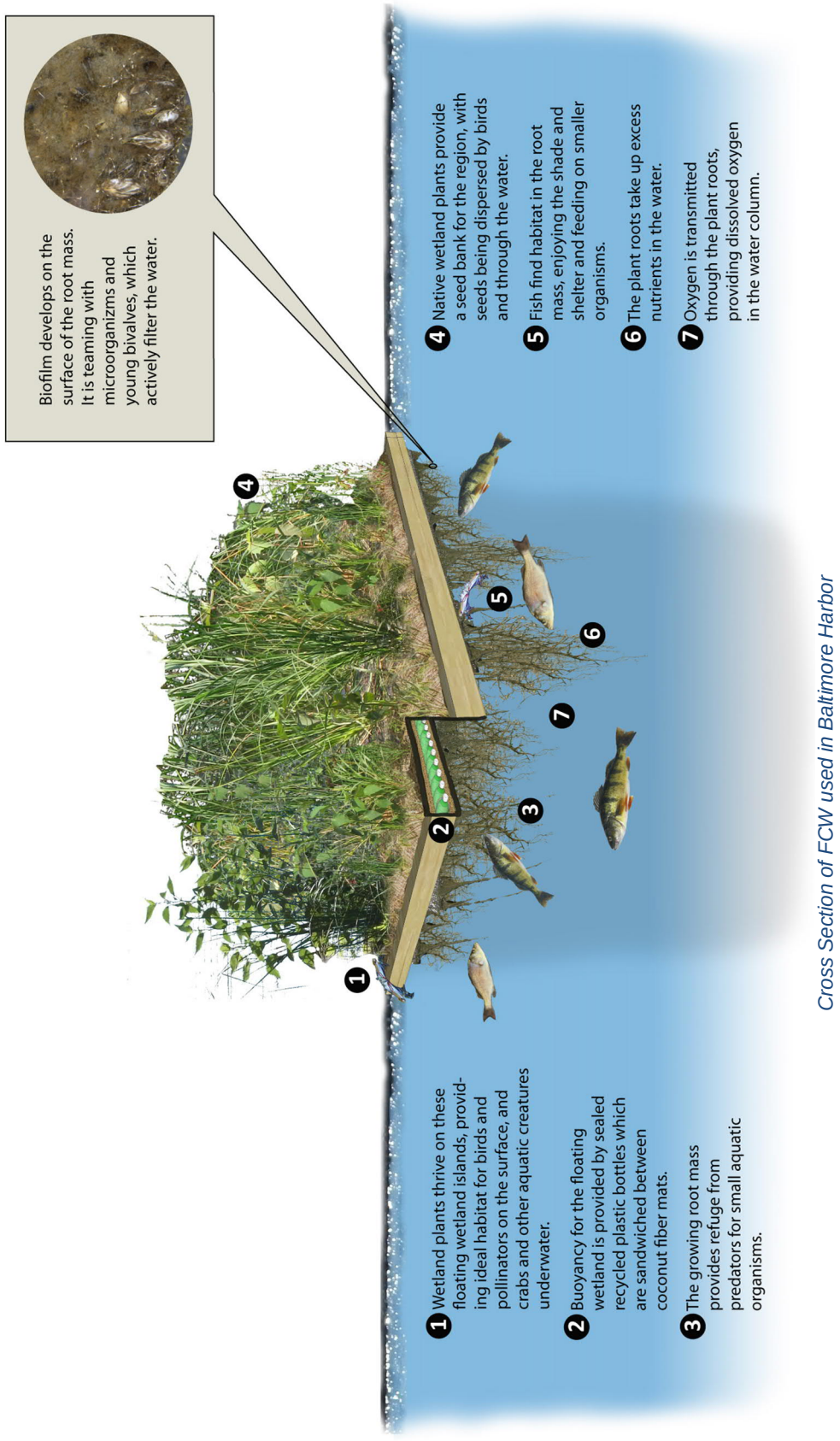
The FCW can be designed into any shape or size, but a typical section is rectangular. Any number of sections can be connected together by cables to create a unit.

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.

Stantec

CONCEPTUAL APPROACH TO MEET ORLEANS WATER QUALITY GOALS

MARCH, 2015

TOWN OF ORLEANS
MASSACHUSETTS

N

0 600 1,200 2,400 3,600 4,800
Feet

Rock Harbor Watershed:

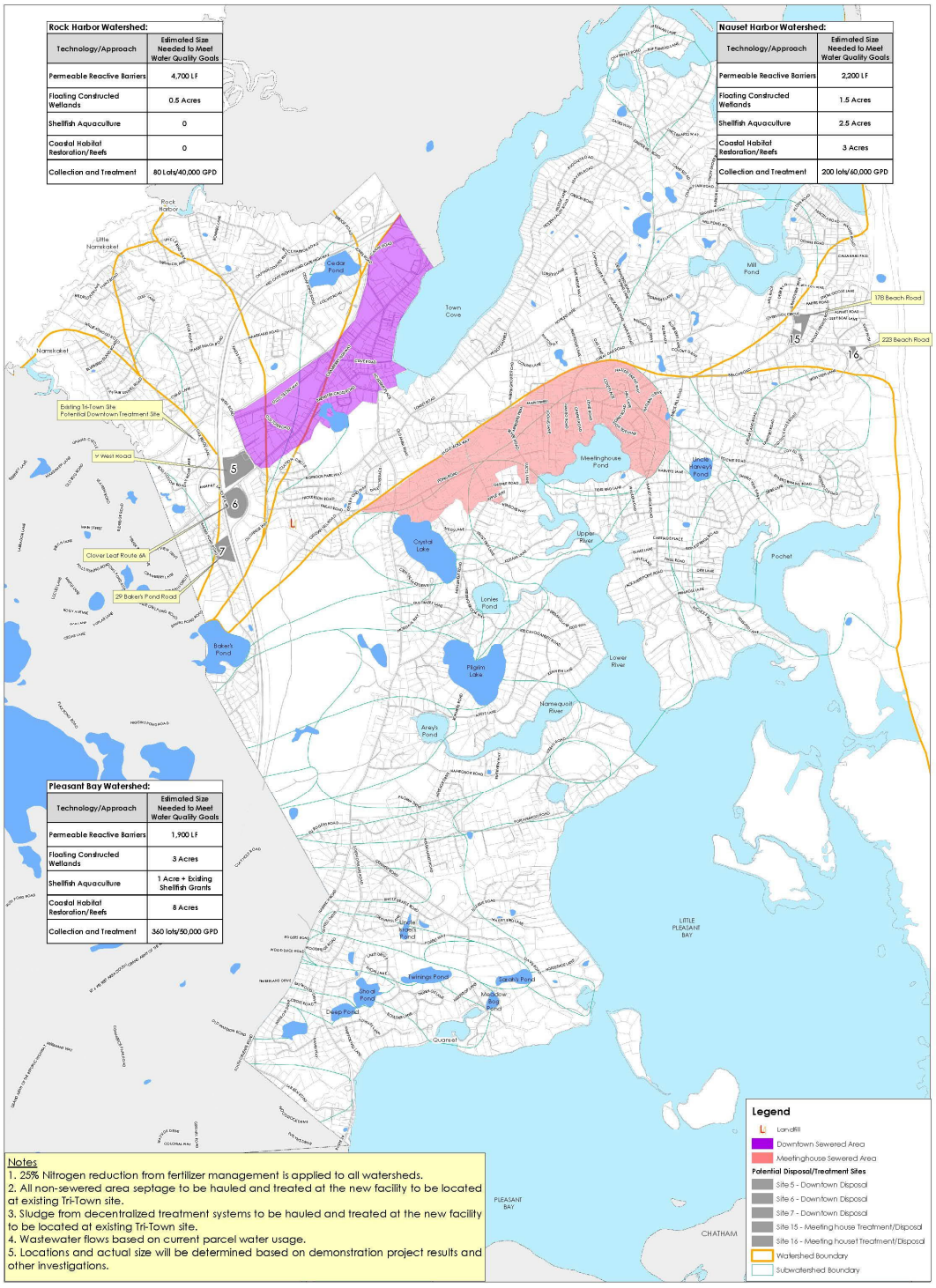
Technology/Approach	Estimated Size Needed to Meet Water Quality Goals
Permeable Reactive Barriers	4,700 LF
Floating Constructed Wetlands	0.5 Acres
Shellfish Aquaculture	0
Coastal Habitat Restoration/Reefs	0
Collection and Treatment	80 lots/40,000 GPD

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



Notes
1. 25% Nitrogen reduction from fertilizer management is applied to all watersheds.
2. All non-sewered area septage to be hauled and treated at the new facility to be located at existing Tri-Town site.
3. Sludge from decentralized treatment systems to be hauled and treated at the new facility to be located at existing Tri-Town site.
4. Wastewater flows based on current parcel water usage.
5. Locations and actual size will be determined based on demonstration project results and other investigations.

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 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; and
- Upper River.

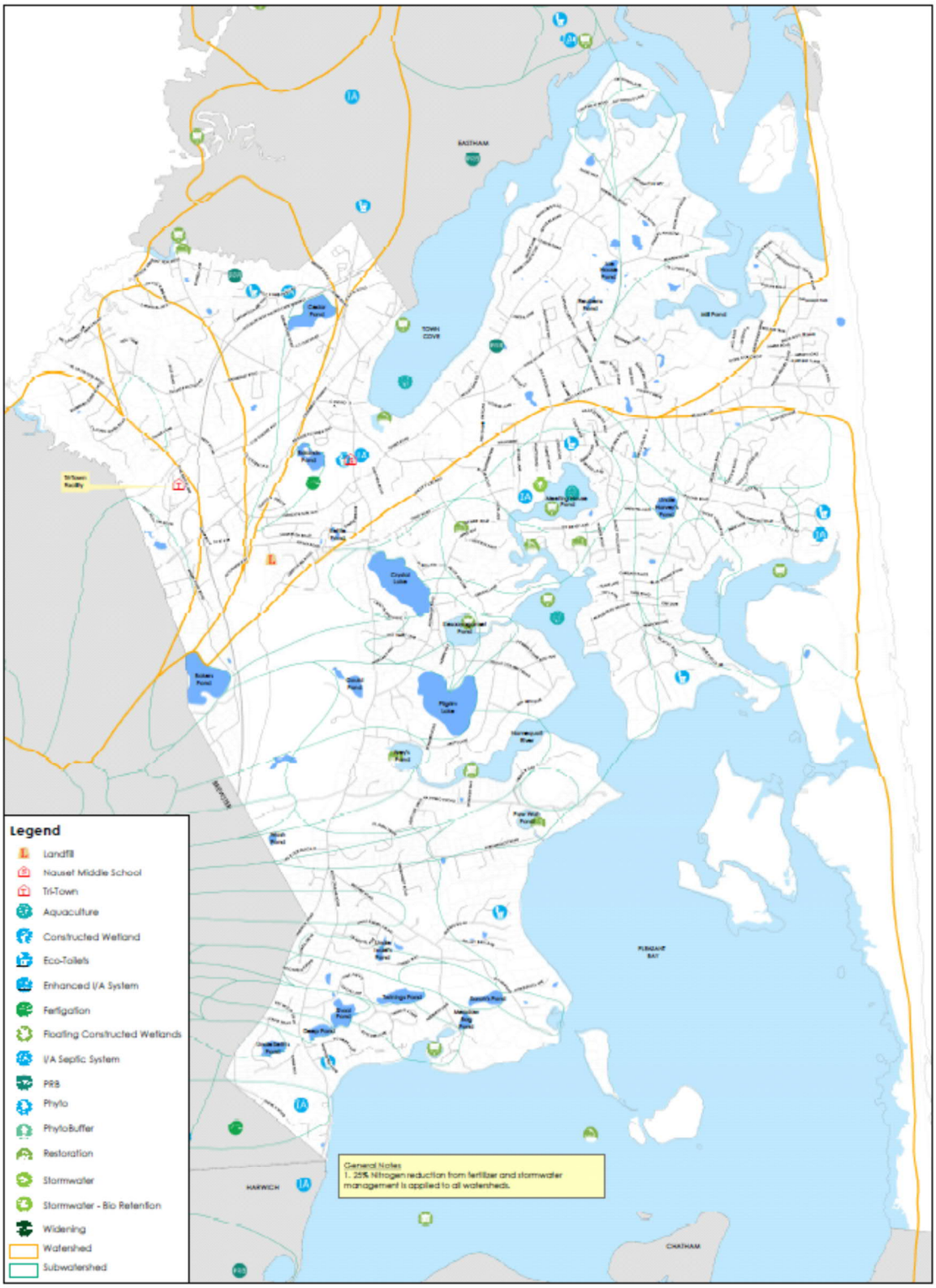
d. 2015 Site Reconnaissance

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; and
- Upper River.


Legend
Landfill
Nauset Middle School
Tri-Town
Aquaculture
Constructed Wetland
Eco-Toilets
Enhanced I/A System
Fertigation
Floating Constructed Wetlands
I/A Septic System
PRB
Phyto
PhytoBuffer
Restoration
Stormwater
Stormwater - Bio Retention
Widening
Watershed
Subwatershed
General Notes
1. 25% Nitrogen reduction from fertilizer and stormwater management is applied to all watersheds.
EASTHAM
HARWICH
CHATHAM
Stantec
CCC 208 PRELIMINARY
NON-TRADITIONAL SCENARIO MAP
TOWN OF ORLEANS
MASSACHUSETTS
SEPTEMBER, 2014
N

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; and
- 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

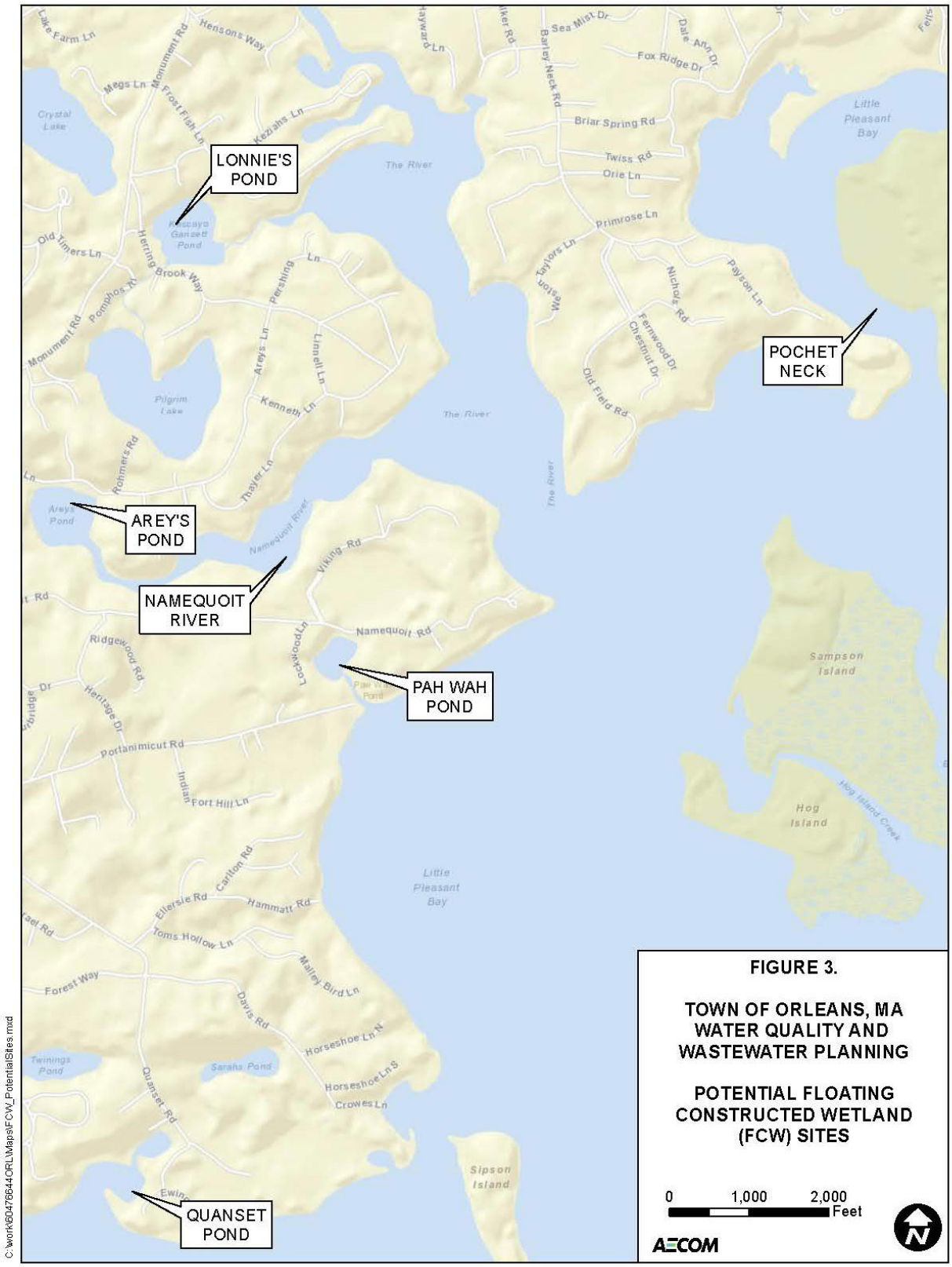
All sites are located within the Pleasant Bay Estuary Area of Critical Environmental Concern, as designated in 1987 because of the area's extraordinary natural resources.

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.

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.


LONNIE'S POND
POCHET NECK
AREY'S POND
NAMEQUOIT RIVER
PAH WAH POND
QUANSET POND
The River
Little Pleasant Bay
Sampson Island
Hog Island
Sipson Island
Pilgrim Lake
Crystal Lake
Sea Mist Dr
Fox Ridge Dr
Briar Spring Rd
Twiss Rd
Orie Ln
Primrose Ln
Taylors Ln
Nichols Rd
Payson Ln
Fernwood Dr
Chestnut Dr
Old Field Rd
Lake Farm Ln
Megs Ln
Monument Rd
Frost Fish Ln
Hensons Way
Kezjahs Ln
Old Timers Ln
Herring Brook Way
Pomphos Rd
Pershing Ln
Arey's Ln
Linnell Ln
Kenneth Ln
Rohmers Rd
Thayer Ln
Viking Rd
Namequoit Rd
Lockwood Ln
Ridgewood Rd
Heritage Dr
Portanimicut Rd
Indian Fort Hill Ln
Carlton Rd
Ellersie Rd
Hammatt Rd
Toms Hollow Ln
Forest Way
Mallory Bird Ln
Davis Rd
Horseshoe Ln N
Horseshoe Ln S
Crowes Ln
Quanset Rd
Twinings Pond
Sarahs Pond
FIGURE 3.
TOWN OF ORLEANS, MA
WATER QUALITY AND
WASTEWATER PLANNING
POTENTIAL FLOATING
CONSTRUCTED WETLAND
(FCW) SITES
0
1,000
2,000
Feet
AECOM
C:\work\60476644\GRL\Maps\FCW_PotentialSites.mxd

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 sub-basins, 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 sub-basin, 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 sub-basin is located just south of the Namequoit River sub-basin, 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 sub-estuary 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 sub-basin 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 sub-basin 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; and
- 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.

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