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Memorandum

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Subject	**Town of Orleans, MA** **Water Quality and Wastewater Planning** **Task Number 3.b – NT Demonstration Projects** **Technical Memorandum on Draft for Site Characterization and Evaluation for Aquaculture/Shellfish Propagation (evaluation criteria and ranking)**
Project Number	60476644
From	Thomas Parece, P.E., AECOM Project Manager
Date	12/19/15

1. Background

a. Purpose

The Site Characterization and Evaluation Technical Memorandum documents the process used to identify, evaluate, rank and ultimately recommend specific shellfish demonstration sites. This Memorandum including the following:

- Description of the initial process that was employed to develop the Orleans Consensus Plan and associated potential demonstration sites;
- Next steps that have been taken in the process of evaluating demonstration sites;
- Data that is available to help evaluate potential demonstration sites;
- Evaluation and ranking of sites based on the site selection matrix and criteria; and
- Recommended demonstration sites paired with specific shellfish propagation approaches (such as bottom planting hard shell clam, oyster reef or oyster aquaculture), and rationale for selection.

In addition, key terms are defined including the categories of data that were evaluated. The site selection criteria and ranking 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 shellfish based non-traditional technology demonstration projects. The assessment will be used to select the best possible site(s) for preliminary engineering, which will include drawings, preliminary specifications, cost estimates, funding sources and monitoring plans.

b. Definition of Aquaculture and Coastal Habitat Restoration (CHR)

In order to establish a consistent meaning of aquaculture and CHR in the context of this Technical Memorandum, these terms are defined as follows:

Aquaculture: the farming of shellfish in controlled or selected marine environments as single, unattached units, for eventual harvest. Farming involves using gear such as cages, floating bags or trays. Direct planting of shellfish on the sea floor after a period of growing in gear is also considered aquaculture. Marine aquaculture is usually located in bodies of saltwater, with land-based, manmade systems such as upweller tanks used for certain initial phases of growth.

Shellfish farming typically includes activities that seek to enhance production, including:

- Moving or splitting populations of shellfish to control density within gear;
- Locating shellfish in specific regions of the water column with better growing conditions; and
- Protecting from predation.

In Orleans, the most suitable shellfish species for aquaculture include American (or Eastern) oyster (Crassostrea virginica), hard clam (or northern quahog) (Mercenaria mercenaria), and blue mussel (Mytilus edulis). Shellfish aquaculture for the purpose of this Technical Memorandum involves growing single oysters and/or quahogs in gear such as bags, trays or cages until these shellfish reach a suitable size for bottom planting or harvest. Aquaculture systems that require supplemental feeding to support growth are not under consideration. Blue mussels were evaluated and rejected for a demonstration project due to the difficulty of growing this species at this time. Nitrogen-removal calculations are based on average shellfish uptake as demonstrated in published literature as well as through personal experience by the assembled Team.

Coastal Habitat Restoration (CHR): creating or rehabilitating native shellfish habitats; creating an ecosystem that includes a combination of shellfish species and associated organisms and plants that remove nitrogen from the water column. Establishing new shellfish areas and reef systems where native shellfish species have not existed historically is also considered CHR. Dense populations of oysters are often referred to as oyster bottoms, oyster beds, oyster bars, oyster banks, or oyster reefs. These terms refer to large colonial aggregations of living oysters and oyster shells that provide habitat for other species. Quahog bottom planting is also CHR, as propagation restores native shellfish populations, habitats and improves bottom sediment. Nitrogen-removal calculations are based on average shellfish uptake as demonstrated in published literature as well as through personal experience by the assembled Team.

Growing options include (1) bottom planting of shellfish raised from seed through hatcheries and propagation programs, (2) growing spat-on-shell (remote set) in trays or bags, and (3) reef establishment programs by means of substrate enhancement (cultch placement). CHR may also involve establishing and/or enhancing estuary salt marshes and eelgrass beds as part of an effort to create suitable coastal habitats.

Oyster Reefs can be established both for harvest as well as for "no take" sanctuaries. Both contribute important ecosystems services, including:

- Nitrogen uptake;
- Improved sediment quality;
- Increased biological diversity; and
- Shoreline protection from erosion and storms.

The distinction is that "no take" sanctuaries are reefs where removal of oysters for harvest is prohibited for a period of 5 years or more, to enable the reef structure to be established without the inevitable disturbances from harvest activities. No take areas also enable oysters to continue to grow after they have reached harvest size. These more mature shellfish are expected to produce larger spawns. In addition, allowing oysters to grow and spawn for several generations is expected to promote a more disease resistant population. Spawning sanctuaries are believed to increase native populations and thus support commercial and recreational harvest more than reefs that are continuously harvested (Frankic et al, 2015; Frankic and Cataldo, 2007; Jones, 2006).

2. Introduction

a. Consensus Plan Description

The Orleans Water Quality Advisory Panel (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. Initially, a Hybrid Plan was designed that included specific sites for aquaculture and coastal habitat restoration (CHR), as well as permeable reactive barriers (PRB) and floating constructed wetlands (FCW). The number of acres of shellfish growing area (as well as linear feet of PRBs and square footage for FCW) were quantified to achieve specific nitrogen-removal targets. This exercise was undertaken to ensure that the quantities of shellfish (and all other non-traditional technologies) proposed in the Consensus Plan were feasible to install. These specific locations became the basis for potential demonstration site locations for aquaculture and CHR, as well as FCWs and PRBs.

The Hybrid Plan was vetted through the OWQAP during three meetings, including a day-long workshop. This iterative process resulted in a draft Consensus Plan that included a combination of non-traditional and traditional technologies. Once the feasibility of using shellfish and other non-traditional technologies as part of the Town's nutrient management strategy was established, the OWQAP decided that the final Consensus Plan would not specify exact growing locations, but instead focus on overall area of shellfish and other alternative technologies needed to remove the appropriate mass of nitrogen at the watershed level.

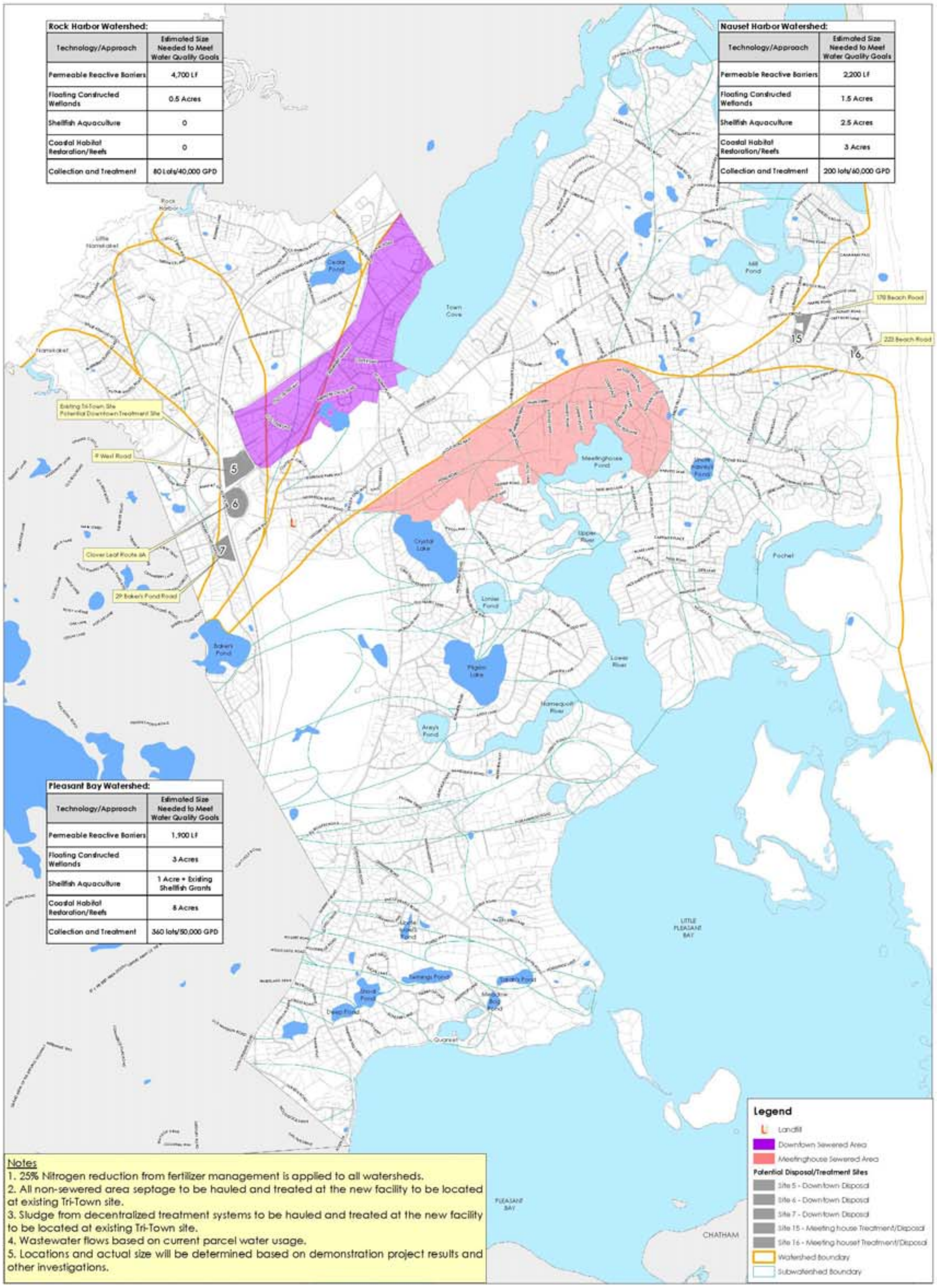
The resulting map (Figure. 1), entitled Conceptual Approach to Meet Orleans Water Quality Goals (March 2015) shows the agreed upon water quality management plan and includes 5.5 acres of shellfish in the Nauset Harbor watershed and 9 acres of shellfish in Pleasant Bay. Neither coastal habitat restoration nor aquaculture is part of the plan for the Rock Harbor watershed. This map also specifies acreages for FCW and linear feet of PRBs.

CONCEPTUAL APPROACH TO MEET ORLEANS WATER QUALITY GOALS

Stantec

TOWN OF ORLEANS
MASSACHUSETTS

MARCH, 2015



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 Non-Traditional Scenarios that would meet the regulatory requirements for nitrogen formalized as Total Maximum Daily Loads (TMDLs) for Orleans' impaired water bodies. The Traditional Scenario for Orleans used centralized sewers exclusively. The Non-Traditional 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 technologies in the Commission's Non-Traditional Scenario included PRBs, FCWs, CHR, shellfish aquaculture, fertigation, composting and urine-diverting toilets and innovative/alternative septic systems. In order to ensure consistency with this established regulatory framework, the Non-Traditional Scenario developed by the Commission became the starting point for customizing a non-traditional bookend for the OWQAP and consensus-building process.

This planning and design process for tailoring a non-traditional bookend for Orleans included studying the information prepared by the CCC, and collecting and analyzing a significant amount of additional local data that was 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. Paper records on the history of local aquaculture, and Town shellfish propagation were aggregated into a database for trending and other analyses. Site visits both by land and by water were conducted to validate locations for shellfish aquaculture and CHR. Interviews with the Orleans Shellfish Constable, the former Shellfish Constable, and local shellfishers were also conducted to verify initial findings.

This local data was used to:

- Evaluate depth to groundwater and aquifer thickness for PRB installations;
- Assess roads and neighborhoods for PRB installations;
- Classify water bodies in terms of suitability for aquaculture and/or CHR based on water quality data contained in Massachusetts Estuaries Project (MEP) Reports and data synthesis from the Pleasant Bay Alliance;
- Inventory potential and existing use conflicts (boating, moorings, aesthetic preferences);
- Identify specific areas for shellfish growing within waterbody; and
- Recommend different species for specific areas, including quahogs, oysters, and mussels.

This local data collection and evaluation allowed the Non-Traditional Bookend for Orleans to be based on key validated site parameters, ensuring that the non-traditional technologies were feasible in their planned locations. In addition, a Technical Memorandum on Non-Traditional 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 non-traditional technologies were presented and thoroughly discussed during the October 8, 2014 OWQAP Stakeholder meeting. Based on this technical review, as well as direction from the OWQAP, specific non-traditional technologies were then selected to be used to create a "Hybrid Plan" that included both non-traditional as well as traditional technologies for Orleans. The Hybrid Plan showed both technologies in specific locations in order to verify that appropriate nutrient loads could be removed.

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 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, the OWQAP received a Technology Evaluation Decision Support Tool that allowed risks and benefits of each technology to be evaluated by subwatershed. Preliminary comparative costs were also presented on a relative dollars/kilogram of nitrogen removed basis. Spreadsheets with ranking for each subwatershed are included in Appendix B.

Ranked categories include:

- Nutrient removal certainty: nitrogen (saltwater), phosphorus (freshwater);
- Implementation certainty;
- Other benefits: ecosystems, economic, social;
- Adaptability to uncertainty in nutrient-reduction goals and build-out; and
- Contaminants of emerging concern (CEC) removal.
- Overall cost

Based on these criteria, all sites shown on the Hybrid Plan for both shellfish aquaculture and CHR were retained. These locations became the initial list of possible locations for demonstration projects, needed to validate the feasibility and nutrient-removal capacity of shellfish in Orleans. The following sites and activities (aquaculture and/or CHR) were identified as part of the process of defining the Consensus Plan and are being reviewed in greater detail as part of this next phase of work, currently underway:

- Town Cove (both aquaculture and CHR);
- Mill Pond (both aquaculture and CHR);
- Little Pleasant Bay (both aquaculture and CHR);
- Arey's Pond (aquaculture);
- Pochet (CHR);
- Lower River (CHR); and
- Quanset Pond (CHR).

d. Current Process of Site Review and Validation

The initial shellfish sites, taken from the Hybrid Plan developed during the OWQAP process were further evaluated by the Shellfish Technical Team that was subcontracted by AECOM to evaluate demonstration sites and prepare this Technical Memorandum. The specific methodology used for in-depth site evaluations included the following steps:

- Review Nauset Harbor and Pleasant Bay watersheds to identify potential demonstration locations that may not have been identified during the first phase of planning;

- Study available data (water quality and other data);
- Conduct land-based and water-based field investigations of potential sites;
- Discuss potential demonstration sites with Orleans Shellfish Constable and Harbormaster;
- Refine criteria to be used in the Site Selection Matrix;
- Rank sites based on criteria using Site Selection Matrix;
- Assess the relative importance of each criteria to establish a weighting of criteria if appropriate;
- Perform QA/QC of initial ranking and criteria weighting;
- Review preferred demonstration sites that resulted from the Site Selection Matrix process;
- Submit Site Selection Matrix to Town of Orleans for review; and
- Recommend demonstration site locations.

This Technical Memorandum reports on the findings of these tasks.

3. Description of Proposed Sites

a. Definitions: Data Parameters

There are two categories of data used to assess potential demonstration locations: (1) information on site ecology, which includes the environmental conditions in the water bodies where shellfish will be raised, and (2) information on the surrounding environment, which addresses land use characteristics, as well as public and private uses associated with the demonstration sites. The specific data parameters associated with each data category are:

Site Ecology

- Water quality data which includes salinity, dissolved oxygen (DO), chlorophyll a, total nitrogen (TN), dissolved organic nitrogen (DON), particulate organic matter (POM), pH, and temperature;
- Tide and water flow (circulation);
- Bathymetry;
- Benthic Conditions;
- Eelgrass bed locations; and
- Local knowledge of shellfish species, predation and shellfishing activities at these sites.

Surrounding Environment

- Type and location of current uses;
- Abutter interests/potential conflicts;

- Acreage available within water bodies;
- Access points/easement requirements;
- Land ownership; and
- Viability of using existing shellfish grants as a demonstration.

Each of these data parameters is defined or explained for use in site selection as follows:

Site Ecology Terms

- **Bathymetry:** a measure of water depth.
- **Benthic Conditions:** the type of sediment present at a given site, expressed as grain size.
- **Chlorophyll *a*:** a green pigment responsible for the absorption of light to provide energy for photosynthesis. Phaeophytin *a* is also a photosynthetic pigment, often produced by the degradation of chlorophyll *a*. Chlorophyll *a*, as well as total pigment concentration can be used as a proxy for food concentration.
- **Dissolved Oxygen:** The amount of elemental oxygen, O_2, in solution under existing atmospheric pressure and temperature. Low levels of dissolved oxygen (DO) can slow the growth rate and reduce the survival of shellfish (Gosling 2003; Whetstone et al 2005).
- **Eelgrass bed locations:** mapped areas where eelgrass is currently growing.
- **Total Nitrogen:** the combined sum of all organic and inorganic forms of nitrogen in a water sample. These forms of nitrogen can include nitrate, nitrite, ammonia, particulate organic nitrogen and dissolved organic nitrogen.
- **Dissolved Organic Nitrogen**: the soluble form of nitrogen contained in organic (carbon-based) compounds such as amino acids, peptides, humic substances and protein.
- **Local knowledge of shellfish species, predation and shellfishing:** information gathered from Orleans shellfish constable (past and present), harbormaster, and local shellfishers.
- **Particulate Organic Matter:** the non-soluble components that can be filtered out of a water sample.
- **pH:** an expression of the acid-base relationship designated as the logarithm of the reciprocal of the hydrogen-ion concentration. The value of 7.0 expresses neutral solutions; values decreasing below 7.0 represent increasingly acidic solutions; values increasing above 7.0 represent increasingly basic solutions.
- **Salinity:** concentration of sodium, potassium, magnesium, calcium, bicarbonate, carbonate, sulfate, and halides (chloride, fluoride, bromide) in water.
- **Turbidity:** the relative clarity of a liquid, determined by measuring the amount of light that is scattered by suspended particles in the water column. The presence of suspended or colloidal matter or planktonic organisms reduces light penetration and increases turbidity.

- **Tide and Water Flow:** refers to the circulation of water within a site; currents and tidal exchange can affect both food and oxygen availability, as well as larval dispersion, transport and fate (Brumbaugh et al 2005).

Surrounding Environment Terms

- **Type and location of current uses:** there are other activities that occur on or near the site, such as boating swimming, and wild shellfish harvesting, which could limit the ability to install a demonstration project.

- **Abutter interests/potential conflicts:** neighbors are not likely to object to a well-designed demonstration location near them.

- **Acreage available within water bodies:** acreage must be sufficient for a demonstration at the site.

- **Access points/easement requirements**: a convenient, public location is available from which to access the site for installation, operation, and maintenance of the demonstration.

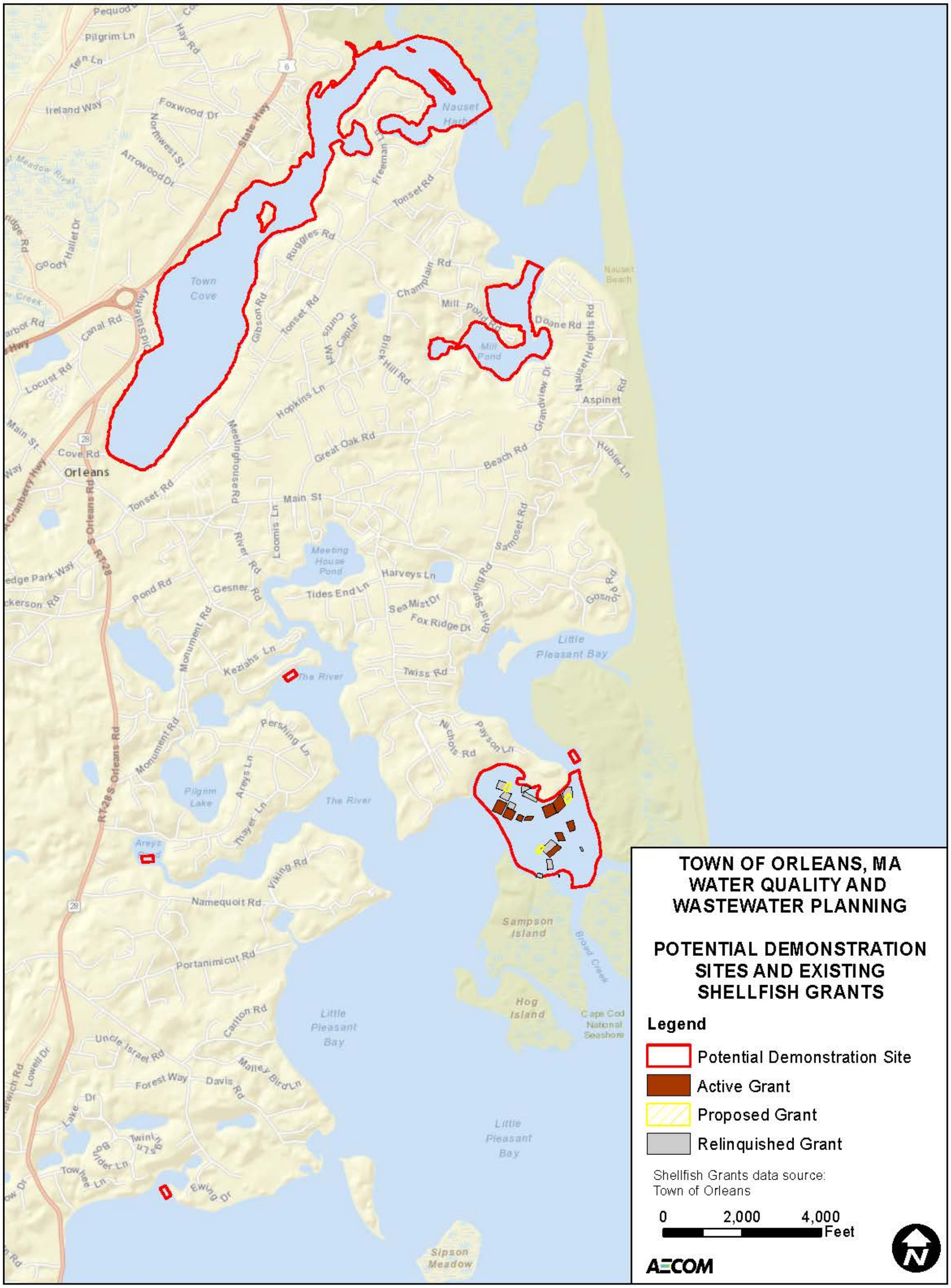
- **Land ownership:** there are parcels owned privately that limit or preclude access to the site.

- **Viability of using existing shellfish grants as a demonstration**: there may be an advantage to working with current holders of shellfish grants in Little Pleasant Bay to implement a demonstration project.

b. Introduction to Site Descriptions

Review of Town Cove and Mill Pond for demonstration locations considered the entire waterbody. The Shellfish Technical team conducted a desktop analysis, land-based field assessment and water-based survey of Pleasant Bay and determined that no additional demonstrations sites needed to be evaluated. Seven (7) potential demonstration sites were evaluated based on site ecology and surrounding environment parameters. These sites, shown in Figure 2, include:

- Town Cove
- Mill Pond
- Little Pleasant Bay
- Arey's Pond
- Pochet
- Lower River
- Quanset Pond


TOWN OF ORLEANS, MA
WATER QUALITY AND WASTEWATER PLANNING
POTENTIAL DEMONSTRATION SITES AND EXISTING SHELLFISH GRANTS
Legend
Potential Demonstration Site
Active Grant
Proposed Grant
Relinquished Grant
Shellfish Grants data source: Town of Orleans
0
2,000
4,000
Feet
AECOM
Town Cove
Nauset Harbor
Mill Pond
Meeting House Pond
Little Pleasant Bay
The River
Pilgrim Lake
Pleasant Bay
Sampson Island
Hog Island
Sipson Meadow
Orleans
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Key site ecological factors assessed include food availability, salinity and temperature because they are the primary water quality determinants of quahog and oyster distribution and abundance (Menzel 1989; Gosling 2003). Dissolved oxygen (DO) is also a significant parameter, as low levels of DO can limit growth and survival. These constituents are considered threshold factors in assessing site suitability.

The major natural source of food in marine environments is phytoplankton, or algae. Phytoplankton contain chlorophyll a, therefore concentrations of chlorophyll a reflect food availability. Phaeophytin a is also a pigment found in algae. Chlorophyll a data, and in some cases total pigment data (chlorophyll a + pheophytin a) is available for each site. Quahogs and oysters are tolerant of wide temperature ranges; because they enter a dormant phase when water temperatures are below 4°C/40°F, both can survive temperatures below 0°C. Both species also tolerate a wide range of salinity. However, predation has been observed to decrease at salinities that are lower than ocean water (approximately 35 ppt). The temperature is consistent for all sites. Salinity varies among sites with data presented within each site description. Field evidence demonstrates that both oysters and quahogs are viable at current temperatures and salinities. All of the potential demonstration sites experience low DO concentrations at the bottom of the water column. These data are presented for each site within the site descriptions in Section 3.c.

Site ecological information related to predation, bottom conditions and bathymetry is also presented, including absence of eelgrass beds, and sediment type, as these factors apply to the type of demonstration viable at the site. Each site description details the particular issues that favor a certain type of demonstration project. For example, the presence of significant populations of predators limits oyster growing locations. The sediment conditions at each site dictate whether bottom planting is feasible and whether oysters or quahogs are more appropriate. Oysters require a hard substrate on which to set during their late larval stage, or sandy bottom if they are planted as juvenile single, while quahogs can tolerate a sand/mud mix but can also grow in coarse substrates such as sand and gravel (Gosling 2003).

Based on a literature review, threshold site ecology parameters should have the following range of values:

Target Values for Site Ecology Parameters: Oysters

- Optimal salinity: 14 to 28 parts per thousand
- Optimal dissolved oxygen: >4 mg/L
- Food availability (Chlorophyll a): >2 µg/L
- Absence of major populations of predators such as oyster drill
- Absence of eelgrass
- Benthic conditions: hard bottom sediment
- pH range suitable for larvae (most sensitive stage of life cycle): 6.75 to 8.75
- Suitable annual temperature range: > -2 to ≤ 35 °C
- Optimal bathymetry (intertidal): 1 to 30 meters

Based on Whetstone, 2005; Gosling, 2003; Dame, 1996; Menzel. 1989; Stanley 1983.

Target Values for Site Ecology Parameters: Quahogs

- Optimal salinity: 20 to 25 parts per thousand
- Optimal dissolved oxygen: >4 mg/L
- Food availability (Chlorophyll a): >2 µg/L
- Absence of eelgrass
- Benthic conditions: bottom sediment a mix of sand and mud
- Suitable annual temperature range: > -6 to ≤ 35 °C
- Optimal bathymetry (intertidal): 1 to15 meters

Based on Gosling 2003; Dame 1996; Lorio 1994; Sellers 1984.

Surrounding Environment Data

Land use, access to the water, current uses, and neighborhood support for a demonstration are important considerations that are unique to each site. Specific access points are identified, and the character of the neighborhoods surrounding each potential demonstration site is discussed. Public uses such as boating, swimming and shell fishing are also critical. All sites have some form of public access available. The most convenient access is land-based, where a boat is not required to install, operate and maintain the demonstration project. Some of the proposed demonstration sites have fewer conflicting uses and more surface water on which to locate and operate. A preliminary assessment regarding the likelihood of neighbor support for a demonstration is also presented. These aspects of the surrounding environment are detailed in the site descriptions.

c. Potential Demonstration Site Descriptions

Nauset Harbor Watershed

(1) Town Cove

General - Town Cove was evaluated for both oyster aquaculture and CHR. An oyster aquaculture demonstration would include growing seed in an upweller, with transfer to floating bags once the seed reaches approximately 8 mm. At the end of the first growing season, oysters would be bottom planted and allowed to grow through a second season for recreational and commercial harvest once the oysters reached market size (3-inch). Some of the first year oysters could be overwintered in the floating bags. CHR would involve expanding the Town's current propagation program by purchasing seed at 25mm and bottom planting these quahogs in suitable locations in Town Cove for recreational and commercial harvest.

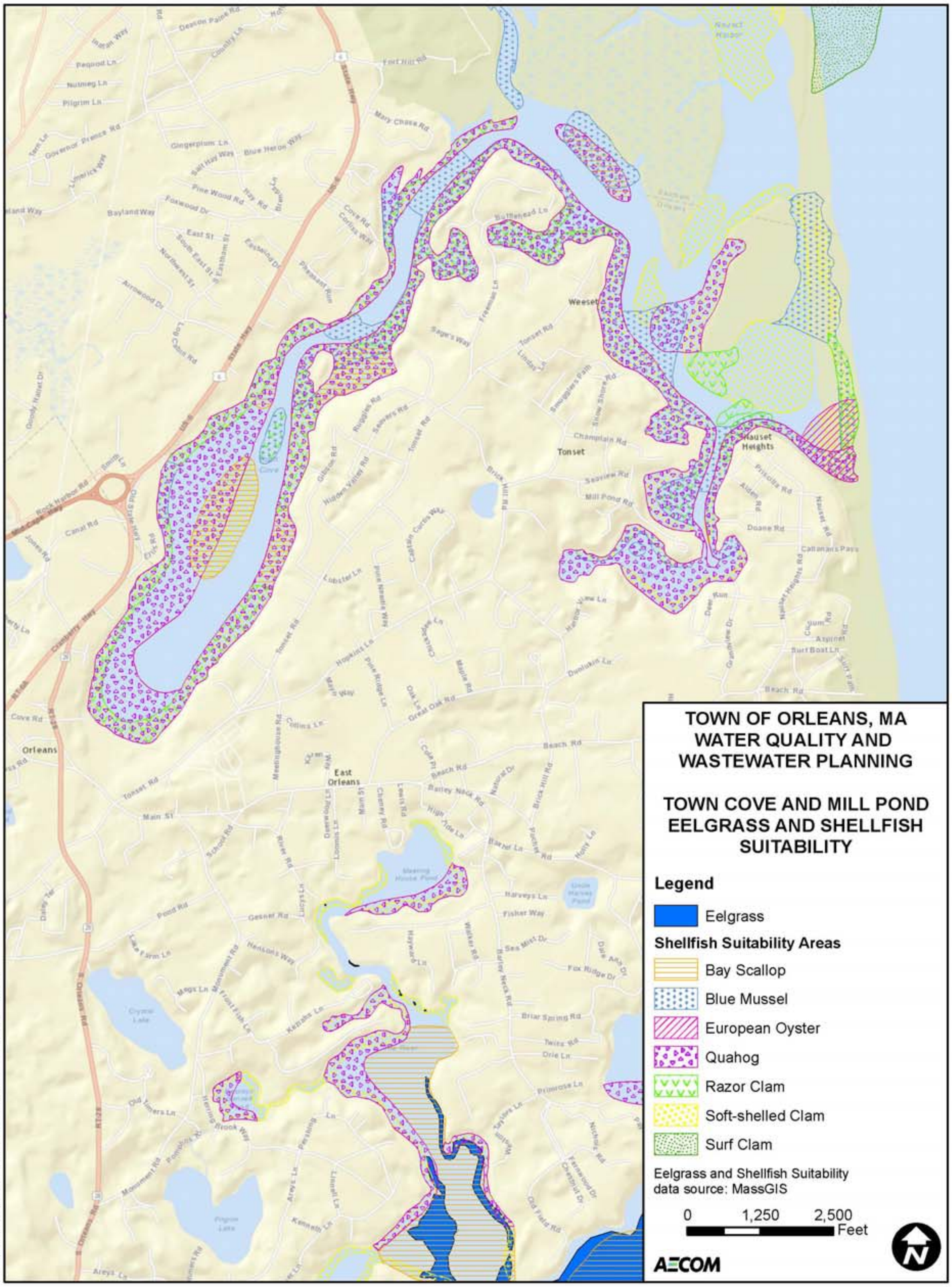
Site Ecology - The MEP Final Report for Nauset Harbor (2012) documents the necessary water quality parameters for Town Cove. Salinity ranges from approximately 32 ppt at the inlet to a minimum of 29 ppt near the head of the cove. Monitoring equipment that collects DO and chlorophyll *a* data in fifteen minute intervals was deployed in Town Cove as part of the MEP field investigations in 2003. This instrument was centrally located in the southern end of the estuary, approximately 1 mile from Hopkins Island and 4 miles from Nauset Inlet. DO levels at the bottom were frequently less than 2 mg/L and periodically approached 0 mg/L. DO levels < 3 mg/L were measured for 38 percent of the 29 day monitoring period. Food availability is indicated by chlorophyll *a* concentrations, which averaged 8.5 µg/L, exceeding the minimum site suitability threshold of 2 µg/L. Both by numerical thresholds as well as field confirmation that both quahogs and oysters are growing in Town Cove, it seems that there is adequate food supply to support shellfish growth in this estuary. Given the low DO concentrations in bottom waters, an oyster aquaculture demonstration would likely need to employ growing systems that suspend shellfish in the upper sections of the water column. Areas within this waterbody with higher DO levels would be better suited to quahog planting, to optimize growth rates. High salinity promotes predation, which is a significant issue in this waterbody.

The suitability of Town Cove for an oyster aquaculture or CHR demonstration is severely limited by the large population of oyster drills (*Urosalpinx cinerea)*. Massachusetts Shellfish Officers association Best Management Practices urge against oyster propagation in areas that experience high predation by oyster drills. For this reason, the use of oyster aquaculture or oyster reefs as part of CHR are not proposed for this site. Macroalgae accumulations also create significant fouling problems for gear-based systems. Because of oyster predation and fouling issues, Town Cove is mainly suitable for bottom propagation of quahogs. A population study to determine baseline quahog numbers and sizes is recommended as a first step, prior to the initiation of a demonstration project. Assessing current quantities of quahogs will provide the basis for evaluating the increase in quahogs from additional propagation efforts undertaken as part of a demonstration.

Town Cove has a waterbody surface area of 390 acres, providing ample area for a shellfish demonstration for quahog propagation. The MEP model estimates a target nitrogen removal load for this sub-watershed of almost 6700 kg N/year. Shellfish suitability areas and eelgrass beds (*Zostera marina*) are shown in Figure 3, derived from MassGIS databases. At present, eelgrass has nearly disappeared from Town Cove: therefore siting conflicts associated with this resource are not expected. According to Division of Marine Fisheries (DMF) mapping, Town Cove has suitable habitat for quahogs and oysters. Historically, the Town has operated a successful quahog propagation program in Town Cove. The Orleans Natural Resources Department currently plants approximately 600,000, one inch (25mm) quahogs annually near Hopkins Island. The existing quahog population has not been quantified. A private aquaculture grant is currently growing oysters in Town Cove. An area around the shoreline, extending to the boat ramp at the Orleans Yacht Club and seaward to a depth of three feet (measured at low tide) is closed for shellfishing by the Shellfish Constable to promote a sustainable year round recreational fishery. These data confirm that portions of Town Cove could support the growth of both oysters and quahogs.

The tide range in Town Cove is approximately 5 - 6 feet. Bathymetry data contained in the MEP Report and field verification with the Orleans Harbormaster document that at mean high tide, Town Cove north of Rocky Point has a maximum depth of 6.5 feet. At low tide, water is less than 2 feet deep. Over half of Town Cove is less than 8 feet deep at mean low tide. There is a basin (near 13 feet at low tide) located midway between Rocky Point and the Orleans Yacht Club, on the east side of Town Cove. Water depths are adequate to support both oyster and quahog growth. Sediment grain size varies throughout Town Cove, with some areas of coarse sand and other areas of fine-grained, organic rich materials.

Surrounding Environment - The land surrounding Town Cove is fully developed, with residential land use on the east side, and commercial uses along route 6A on the western shore. This estuary is a popular recreation destination, enjoyed by boaters of all types, swimmers, and shell fishers. There are several public boat landings, as well as private docks and a marina. Access to any demonstration project would be possible, but would require a boat. Overall, there are no parameters that preclude a demonstration at Town Cove.



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(2) Mill Pond

General - Mill Pond was evaluated for both oyster aquaculture and CHR. An oyster aquaculture demonstration would include growing seed in an upweller, with transfer to floating bags once the seed reaches approximately 8mm. At the end of the first growing season, oysters would be bottom planted and allowed to grow through a second season for recreational and commercial harvest once the oysters reached market size (3”). Some of the first year oysters could be overwintered in the floating bags. CHR involves expanding the Town’s current propagation program by purchasing seed at 25mm and bottom planting these quahogs in suitable locations in Mill Pond for recreational and commercial harvest.

Site Ecology - The MEP Final Report for Nauset Harbor (2012) documents water quality parameters for Mill Pond. Salinity is approximately 30 ppt. Monitoring equipment that collected DO and chlorophyll *a* data in fifteen minute intervals was deployed in Mill Pond as part of the MEP field investigations in 2003. This instrument was located at a depth of 12 feet, off the Mill Pond boat launch, to avoid this estuary’s deep basin, yielding a more representative water sample. This station is approximately 3 miles from Nauset Inlet, in the main basin of Mill Pond. DO levels were typically between 6 mg/L and 8 mg/L. Food availability, indicated by chlorophyll *a* concentrations, averaged 10.8 µg/L, exceeding the minimum site suitability threshold of 2 µg/L. By numerical thresholds as well as field confirmation that both quahogs and oysters are growing in Mill Pond, it seems that there is adequate food supply and DO to support shellfish growth in this estuary. High salinity promotes predation, which is a significant issue in this waterbody.

The suitability of Mill Pond for an oyster aquaculture or CHR demonstration is severely limited by the large population of oyster drills (*Urosalpinx cinerea)*. Massachusetts Shellfish Officers association Best Management Practices urge against oyster propagation in areas that experience high predation by oyster drills. For this reason, the use of oyster aquaculture or oyster reefs as part of CHR are not proposed for this site. Mill Pond is mainly suitable for bottom propagation of quahogs, outside the deep basin. A population study to determine the baseline quahog numbers and sizes is recommended.

Mill Pond has a waterbody surface area of 81 acres, providing ample area for a quahog shellfish demonstration. The MEP model does not estimate a specific target nitrogen removal load for this sub-watershed but the load reduction target for the entire Nauset System, not including Town Cove, is approximately 1900 kg N/year. Shellfish suitability areas and eelgrass beds (*Zostera marina*) are shown in Figure 3, derived from MassGIS databases. Mill Pond does not have a history of eelgrass beds; therefore, siting conflicts with this resource are not anticipated. According to Division of Marine Fisheries (DMF) mapping, Mill Pond has suitable habitat for quahogs and oysters. Historically, the Town has propagated quahogs in Mill Pond, but current populations have not been quantified. These data confirm that both oysters and quahogs could be grown as part of a demonstration.

The tidal range in Mill Pond is approximately 5 - 6 feet. Bathymetry data document that at mean low tide, water depth is an average of 15 to 18 feet. Mill Pond has a deep basin greater than 26 feet. Water depths are adequate to support both oyster and quahog demonstrations. Sediment grain size varies throughout Mill Pond, with some areas of coarse sand and other areas of fine-grained silt, particularly in the deep basin. Quahog propagation should be possible given this sediment regime.

Surrounding Environment - The land surrounding Mill Pond is a developed, residential area. Mill Pond has a family shell fishing area as well as a mooring field. There is also a small public boat launch area off Mill Pond Road. Access to any demonstration project would be possible, but would require a boat. Overall, there are no parameters that preclude a demonstration at this site.

Pleasant Bay Watershed

(1) Little Pleasant Bay

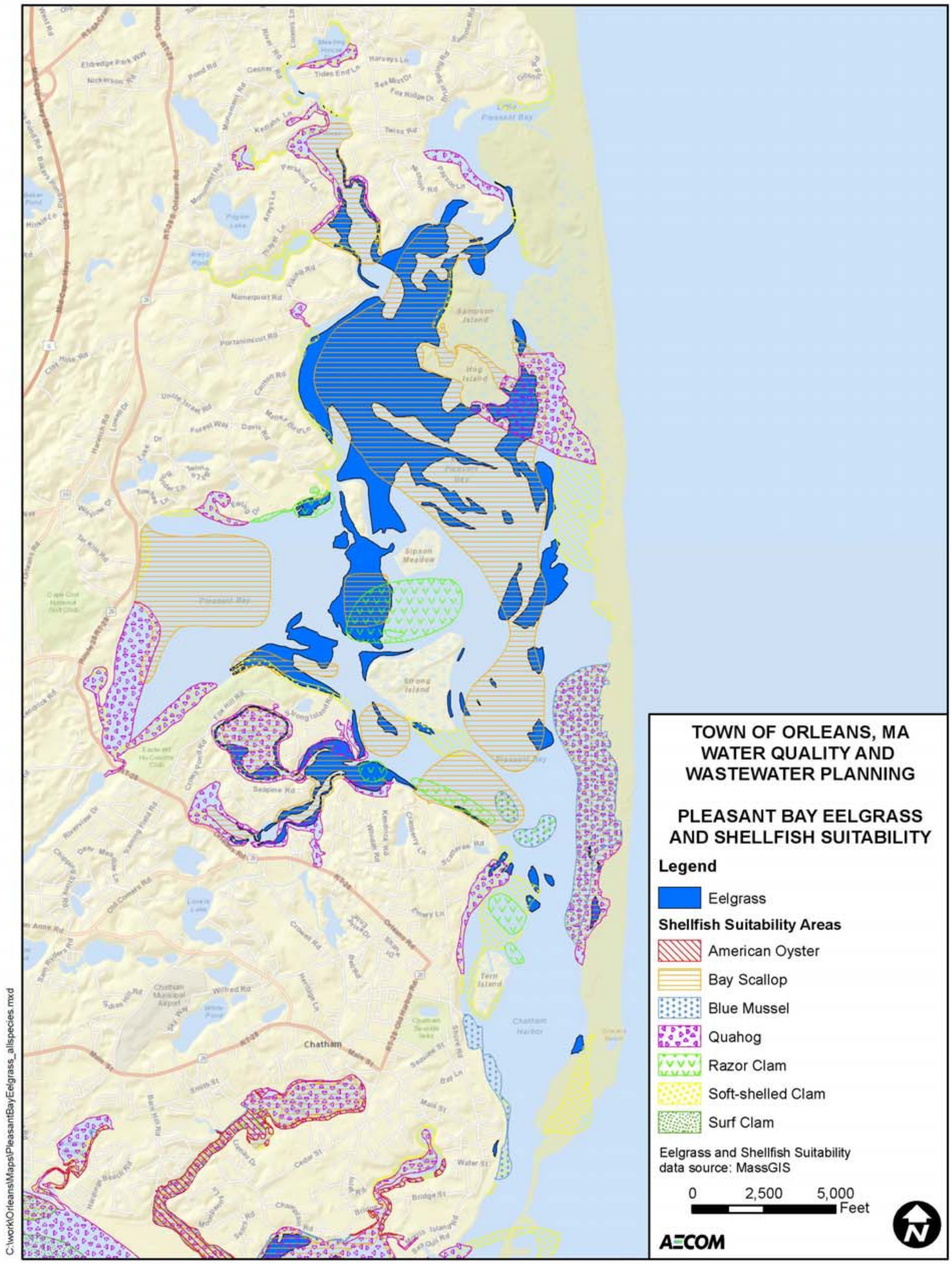
General - Little Pleasant Bay was evaluated for aquaculture and CHR. An oyster aquaculture demonstration would potentially involve working with some of the current operators of the Town's shellfish grants to evaluate and potentially enhance production. CHR would involve purchasing remote set (shells on which oyster seed has been set in controlled environment), growing in floating bags and trays for 8 to 12 weeks, and bottom planting to establish an oyster reef.

Site Ecology - Data for Little Pleasant Bay was found in reports by the MEP (2006) and the Pleasant Bay Alliance Water Quality Monitoring Program (Cadmus Group 2015). MEP did not deploy a monitoring instrument in Little Pleasant Bay as part of their field investigations. However, for the past fifteen years, a program of the Pleasant Bay Alliance's monitoring program collected water quality data during July and August. A monitoring station in Little Pleasant Bay, located between Old Field Point and Sampson Island, is approximately 1800 feet from the current shellfish grants. Based on this data, salinity is approximately 30 ppt and dissolved oxygen levels are over 5 mg/L. Food availability, as indicated by total pigment concentrations (chlorophyll *a* + phaeophytin *a*), declined significantly from 2002 to 2014, dropping from 4.5 μg/L to 2 μg/L. Therefore, food concentrations are approaching the minimum site suitability threshold of 2 μg/L. It will be important to collect data within the existing shellfish grants to determine whether this low concentration of total pigment is also occurring within the grant areas. This information will help develop rational expectations for shellfish harvest yields.

Little Pleasant Bay has a waterbody surface area of 270 acres, with approximately 120 acres identified as acceptable for demonstration sites(the area containing the current shellfish grants). The MEP model estimates a target nitrogen removal load for this sub-watershed of almost 824 kg N/year. The120 acres provide ample area for a shellfish demonstration and expansion. Shellfish suitability areas and eelgrass beds (*Zostera marina*) are shown in Figure 4, derived from MassGIS databases. At present, there are some eelgrass beds in Little Pleasant Bay, but not within the demonstration site area. According to DMF mapping, Little Pleasant Bay does not have suitable habitat for quahogs and oysters. However, both quahog and oyster aquaculture has been productive in this location. A demonstration project in Little Pleasant Bay would build on this success.

The tidal range in Little Pleasant Bay is approximately 5 to 6 feet. Bathymetry data from National Oceanic and Atmospheric Administration (NOAA) show that the depth of Little Pleasant Bay at mean low tide is 2 to 3 feet in many areas. Sediment grain size at the demonstration site in Little Pleasant Bay is dominated by coarse sand, with some areas of fine sand. These features make it possible to operate and maintain a demonstration by standing in the water during low tide, and potentially identifying areas for bottom planting oysters.

Surrounding Environment - The land surrounding the Little Pleasant Bay site is a developed residential area. This estuary is a popular recreation destination, enjoyed by boaters of all types, swimmers, and shellfishers. There are several public boat landings, private docks and a marina at Meetinghouse Pond. Access to any demonstration project would be possible, but would require a boat. Overall, there are no parameters that preclude a demonstration at this site.


TOWN OF ORLEANS, MA
WATER QUALITY AND
WASTEWATER PLANNING
PLEASANT BAY EELGRASS
AND SHELLFISH SUITABILITY
Legend
Eelgrass
Shellfish Suitability Areas
American Oyster
Bay Scallop
Blue Mussel
Quahog
Razor Clam
Soft-shelled Clam
Surf Clam
Eelgrass and Shellfish Suitability
data source: MassGIS
0 2,500 5,000
Feet
AECOM
C:\work\Orleans\Maps\PleasantBayEelgrass_allspecies.mxd

This site provides a unique opportunity to engage the local shellfish grant holders in a demonstration project. These growers are using floating bags, racks and cages for oyster and some quahog aquaculture. There are currently 12 grants in operation, with several new areas proposed by the Shellfish Constable, producing a total combined harvest of approximately 1 million oysters annually. Figure 2 shows the location of these grants. The Orleans Harbormaster and Shellfish Constable both suggested working with these growers to develop a demonstration project because grant holders already have the expertise, infrastructure and interest in aquaculture.

(2) Arey's Pond

General - Arey's Pond was evaluated for oyster aquaculture. An oyster aquaculture demonstration would include growing seed in an upweller, with transfer to floating bags once the seed reaches approximately 8 mm. At the end of the first growing season, oysters would be relayed to other locations for second-year growth because there is no suitable bottom in Arey's Pond. These oysters would then be available for recreational and commercial harvest once the oysters reach market size (3-inch). Some of the first year oysters could be overwintered in the gear and grown out in Arey's Pond, but the gear densities for second year growth are much lower than for first year. Because of space constraints, some of the first year oysters would need to be relayed to other locations.

Site Ecology - The MEP (2006) and the Pleasant Bay Alliance Water Quality Monitoring Program (Cadmus Group 2015) document water quality parameters that are fundamental to shellfish propagation. Salinity in Arey's Pond is approximately 26 ppt. Monitoring equipment that collects DO and chlorophyll *a* data in fifteen minute intervals was deployed in Arey's Pond as part of the MEP field investigations in 2003. The continuous monitoring station was centrally located in the pond. DO concentrations less than 2 mg/L were measured for 63 percent of the 36 day monitoring period. Recent data compiled by the Cadmus Group (2015) confirms that this anoxic condition persists. Food availability, measured by chlorophyll *a* concentrations, averaged 12.5 µg/L in 2003, exceeding minimum site suitability threshold of 2 µg/L. As part of the Pleasant Bay Alliance monitoring program, total pigment concentration (chlorophyll a + phaeophytin) data has been collected since 2008. The total pigment data, therefore food availability, is approximately 7 µg/L. Food supply is adequate to support shellfish growth in this estuary. Given the low DO of bottom waters, oyster aquaculture should employ growing systems that suspend shellfish in the upper sections of the water column.

Arey's Pond has a waterbody surface area of 13 acres, with a limited area for a shellfish demonstration because a mooring field occupies most of the pond. The MEP model estimates a target nitrogen removal load for this sub-watershed of almost 142 kg N/year. Shellfish suitability areas and eelgrass beds (*Zostera marina*) are shown in Figure 3, derived from MassGIS databases. At present there are no eelgrass beds in Arey's Pond, therefore siting conflicts associated with this resource are not anticipated. According to DMF mapping, Arey's Pond has suitable environmental conditions for quahogs and oysters.

The tidal range in Arey's Pond is approximately 5 feet. Bathymetry data from NOAA indicate that at mean low tide the water depth at the center of the pond is 14 feet, and areas along the perimeter and at the entrance from Namequoit River are 6 feet. Sediment grain size in Arey's Pond is dominated by very fine silt, rich in organic matter, precluding bottom planting of shellfish. Water depth dictates that a demonstration project would be worked by boat.

Surrounding Environment - The land surrounding Arey's Pond is a densely developed residential area. This estuary contains a dense mooring field covering most of the water area. Arey's Pond has a public boat landing, private docks and a marina. The marina has an upweller that is used for small-scale oyster propagation. Access to a demonstration project would be possible, but would require a boat for operation and maintenance and a confirmation of support from the neighbors that has been initially expressed. Overall, there are no parameters that preclude a demonstration at this site.

(3) Pochet

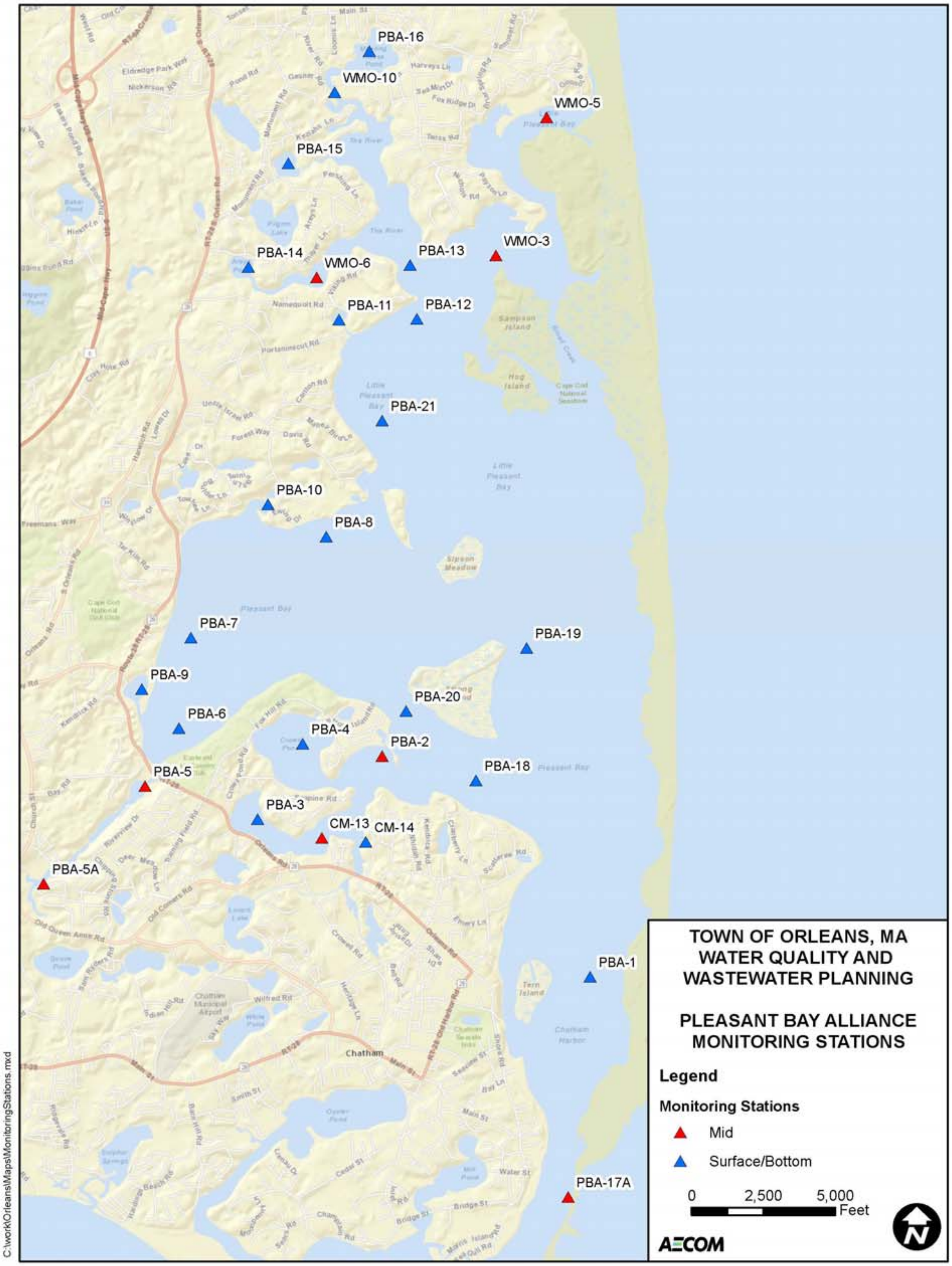
General - Pochet was evaluated for CHR, which would involve purchasing remote set (shells on which oyster seed has been set in controlled environment), growing in floating bags and trays for 8 to 12 weeks, and bottom planting to establish a reef environment.

Site Ecology - The MEP (2006) and the Pleasant Bay Alliance Water Quality Monitoring Program (Cadmus Group 2015) document water quality parameters for Pochet. Salinity in Pochet is approximately 30 ppt. Monitoring equipment that collects DO and chlorophyll *a* data in fifteen minute intervals was deployed in Pochet as part of the MEP field investigations in 2003. However, the station is approximately 2000 feet from the proposed demonstration sites. DO levels less than 5 mg/L but greater than 4 mg/L were measured for 50 percent of the 52 day monitoring period. Recent data compiled by the Cadmus Group (2015) shows that since 2008, DO levels have been approximately 3 mg/L at a monitoring station that is closer to the head of Pochet, approximately 3000 feet (linear distance) from the demonstration site. Figure 5 shows the Pleasant Bay Alliance monitoring station locations. Food availability, measured by chlorophyll *a* concentrations, averaged 5 µg/L during the 2003 MEP field investigation (exceeding minimum site suitability threshold of 2 µg/L). In 2004, the chlorophyll *a* concentration was 3 µg/L at a monitoring station in the same location as the MEP continuous monitoring equipment. There has not been additional data collected near this demonstration site for chlorophyll *a* or total pigment concentrations since 2004. Based on these data, Pochet has adequate food supply and DO levels to support shellfish bottom growth in this estuary.

Pochet has a waterbody surface area of 140 acres, ample area for a shellfish demonstration and expansion. The MEP model estimates a target nitrogen removal load for this sub-watershed of almost 413 kg N/year.

Shellfish suitability areas and eelgrass beds (*Zostera marina*) are shown in Figure 4, derived from MassGIS databases. At present there are two small patches of eelgrass in Pochet, but during the team's field investigation, it was verified that eelgrass is not present at the demonstration site. According to DMF mapping, Pochet has suitable habitat for quahogs and other species not currently being considered for a demonstration. Given the success of oyster aquaculture in the nearby aquaculture grants, it is likely that oysters will grow at this site as well as quahogs.

The tidal range in Pochet is approximately 5 to 6 feet, with the range reported in the MEP Report of up to 9 feet along some areas of Pochet Island. Bathymetry data from NOAA show that this estuary is generally shallow. At mean low tide, the water depth at the Pochet inlet is 2 feet, with depths varying widely near the vicinity of the demonstration site. Field investigation confirmed that the proposed demonstration area is shallow, approximately 3 feet. Sediment grain size at the demonstration site, and in this general area is coarse sand.


TOWN OF ORLEANS, MA
WATER QUALITY AND WASTEWATER PLANNING
PLEASANT BAY ALLIANCE MONITORING STATIONS
Legend
Monitoring Stations
Mid
Surface/Bottom
0
2,500
5,000
Feet
AECOM
PBA-16
WMO-10
WMO-5
PBA-15
PBA-14
WMO-6
PBA-13
WMO-3
PBA-11
PBA-12
PBA-21
PBA-10
PBA-8
PBA-7
PBA-19
PBA-9
PBA-20
PBA-6
PBA-4
PBA-2
PBA-18
PBA-5
PBA-3
CM-13
CM-14
PBA-5A
PBA-1
PBA-17A
Chatham
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Surrounding Environment - he land surrounding Pochet is residential, with a private island bordering the demonstration location. This site is also contained within the boundary of the Cape Cod National Seashore (CCNS). Access to a demonstration project would be possible, but would require a boat for operation and maintenance. Support of the neighbors and permission from the National Park Service is required. These two factors must be addressed before a demonstration project proceeds at this site.

(4) Lower River

General - Lower River was evaluated for aquaculture and CHR along the shore of Kent's Point. CHR involves purchasing remote set (shells on which oyster seed has been set in controlled environment), growing in floating bags and trays for 8 to 12 weeks, and bottom planting to establish a reef environment.

Site Ecology - The MEP (2006) and the Pleasant Bay Alliance Water Quality Monitoring Program (Cadmus Group 2015) document water quality parameters in Lower River. Salinity in Lower River is approximately 30 ppt. Monitoring equipment that collects DO and chlorophyll *a* data in fifteen minute intervals was deployed near Kent's Point as part of the MEP field investigations in 2003. The equipment recorded DO levels between 4 mg/L and 5 mg/L for 78 percent of the 36 day monitoring period. Recent data compiled by the Cadmus Group (2015) in the Upper River indicates that since 2008, DO levels have risen from 4 mg/L to over 5 mg/L. Food availability, measured as chlorophyll *a* concentrations averaged 8.5 μg/L at the Namequoit River monitoring location during the 2003 MEP field investigations, exceeding the minimum site suitability threshold of 2 μg/L. This monitoring location is very near the demonstration site. As part of the Pleasant Bay Alliance monitoring program, total pigment concentrations (chlorophyll *a* + phaeophytin *a*) have been collected at two. Total pigment concentration has been declining since 2000 at both stations, with current concentrations at 3 μg/L. Based on these data, there seems to be adequate food supply and DO levels to support shellfish bottom growth in this estuary.

Lower River near Kent's Point has a waterbody surface area of 20 acres, adequate for a shellfish demonstration. The MEP model estimates a target nitrogen removal load for this sub-watershed of almost 524 kg N/year. Shellfish suitability areas and eelgrass beds (*Zostera marina*) are shown in Figure 3, derived from MassGIS databases. At present there is only a small patch of eelgrass near the eastern edge of the shore, and during the team's field investigation, it was verified that eelgrass is not present at the potential demonstration site. According to DMF mapping, Lower River in the vicinity of Kent's Point has suitable habitat for quahogs, although it is likely that oysters will grow as well.

The tidal range in the Lower River is approximately 5 to 6 feet. Bathymetry data from NOAA indicate that this estuary is generally shallow. At mean low tide, the water depth at the demonstration site is 2 to 4 feet, enabling a demonstration to be worked without a boat. Sediment grain size is dominated by very fine silt throughout this area, which precludes bottom planting of oyster remote set as part of a reef installation as gear, such as trays, would be required.

Surrounding Environment - The land surrounding Lower River is the Kent's Point conservation area. This area has good visibility, visitation and access, which facilitate education and outreach activities. This location can be accessed from the shore, and does not require a boat for installation, operation or maintenance of a demonstration project. This estuary is a popular recreation destination, enjoyed by boaters of all types, swimmers, and walkers. Water skiers and dinghy sailors frequent this area. Floating gear may create user conflicts relating to aesthetics as well as navigation. Overall, there are no parameters that preclude a demonstration at this site, but use conflicts may be an issue.

(5) Quanset Pond

General - Quanset Pond was evaluated for aquaculture and CHR. CHR involves purchasing remote set (shells on which oyster seed has been set in controlled environment), growing in floating bags and trays for 8 to 12 weeks, and bottom planting to establish a reef environment.

Site Ecology - The MEP Final Report for Pleasant Bay (2006) and the Pleasant Bay Alliance Water Quality Monitoring Program Report (Cadmus Group 2015) document water quality parameters for Quanset Pond. Salinity is approximately 30 ppt. A monitoring instrument that collected DO and chlorophyll *a* data in fifteen minute intervals was deployed in Quanset Pond as part of the MEP field investigations in 2003. This station recorded DO levels less than 5 mg/L but greater than 4 mg/L for 48 percent of the 36 day monitoring period. Recent data compiled by the Cadmus Group (2015) indicates that since 2008, DO levels have risen from 4 mg/L to 5 mg/L. Food availability, measured by chlorophyll *a* concentrations averaged 8.9 µg/L at the Quanset Pond monitoring location during the 2003 MEP field investigations, exceeding the minimum site suitability threshold of 2 µg/L. The MEP monitoring location is very near the demonstration site. As part of the Pleasant Bay Alliance monitoring program since 2008, data for total pigment concentrations (chlorophyll a + phaeophytin) has been collected and is approximately 5µg/L. Based on these data, there seems to be adequate food supply, and DO levels to support shellfish bottom growth in this estuary.

Quanset Pond has a waterbody surface area of 13 acres, adequate for a shellfish demonstration and providing some expansion potential. The MEP model estimates a target nitrogen removal load for this sub-watershed of approximately 256 kg N/year. Shellfish suitability areas and eelgrass beds (*Zostera marina*) are shown in Figure 4, derived from MassGIS databases. At present there is no eelgrass near the demonstration site. According to DMF mapping, Quanset Pond has suitable habitat for quahogs, but it is likely that oysters will grow here as well.

The tidal range in Quanset is approximately 5 to 6 feet. Bathymetry data from NOAA indicate that this area is generally shallow. At mean low tide, the depth at the center of Quanset is 7 feet, with a depth of 0.5 feet at the demonstration site. Sediment grain size is dominated by coarse sand at the demonstration location, which is suitable for bottom planting of remote set.

Surrounding Environment - The land surrounding Quanset Pond is moderate-density residential. This area has good visibility, visitation and access, which facilitate education and outreach activities. This location can be accessed from the shore, and does not require a boat for installation, operation or maintenance of a demonstration project. This estuary is a popular recreation destination, with a small mooring field in the deeper part of the basin. The demonstration site would not interfere with navigation or public enjoyment. Aesthetic impacts are mitigated by the fact that the use of surface gear is temporary and that it would be located outside the main beach area. Once the reef is established, any use of floating bags will be discontinued. Overall, there are no parameters that preclude a demonstration at this site.

4. Site Evaluation and Screening Criteria

To facilitate a systematic and objective evaluation of each of the potential demonstration sites, a decision support tool, called a Site Selection Matrix was developed. This Site Selection Matrix includes a number of criteria for Site Suitability, Permitting, and Project Evaluation. Site Suitability criteria address the environmental, land use and implementation characteristics of each proposed demonstration location. Permitting criteria assess the regulatory issues related to each proposed demonstration location. Project evaluation criteria estimate the likelihood of obtaining meaningful results from a proposed demonstration site. Other/Overriding Considerations refer to any threshold issue that precludes a demonstration at a given site.

These criteria were first presented as part of the process of developing the Orleans Consensus Plan. The Shellfish Technical Team refined the criteria after reviewing the Site Ecology and Surrounding Environment data as described above. The Site Selection Matrix now includes the following criteria:

a. Site Suitability

- Available Growing Area/Adequacy of Acreage
- Water Quality Indicators
- Disease/Predation
- Ease of Access
- Aesthetic Impacts
- Representativeness of the Site (Transferability)
- Use Conflicts
- Ability to Co-Locate with other Non-Traditional Technologies

b. Permitting

- Abutter Compatibility
- Wild Harvest Conflicts (DMF)
- Grow-Out to Harvest Size Allowed (DMF)
- Permittability

c. Project Evaluation

- Expected Survival
- Overall Likelihood of Monitoring Plan to Yield Quantified Results

The specific criteria within each evaluation category are defined as follows:

a. Site Suitability

- Available Growing Area/Adequacy of Acreage: an assessment of whether the amount of waterbody surface area is sufficient to implement the demonstration, and whether expansion potential exists.
- Water Quality Indicators: the environmental conditions needed to support shellfish growth. Key parameters include cholorphyll a, dissolved oxygen (DO), and salinity.
- Disease/Predation: presence of a population of predators that are likely to have a significant negative impact on survival of shellfish cultivated as part of a demonstration project.
- Ease of Access: locations are available from which demonstration sites can be installed, operated and maintained.
- Aesthetic Impacts: the visual impression that the project will have on vistas around the site.
- Representativeness of the Site (Transferability): a demonstration at this location would inform potential for shellfish to grow in other areas
- Use Conflicts: the likelihood that the proposed shellfish demonstration can occur without impeding the other activities currently taking place at proposed demonstration sites. This criteria evaluates whether there will be objections from the community of people who use the waters near the proposed demonstration sites both recreationally (boating, swimming, passive enjoyment) and for wild harvest of shellfish.
- Ability to Co-Locate with other Non-Traditional Technologies: As part of a post-demonstration, full-scale implementation strategy it is feasible to add floating constructed wetlands at this site in order to take advantage of any enhanced nitrogen uptake that may result.

b. Permitting

- Abutter Compatibility: the likelihood that the proposed shellfish demonstration can occur without significant objections from adjacent landowners and residents.
- Wild Harvest Conflicts: there are no populations (standing stock) of organisms that are currently harvested, which could trigger a denial of permission from DMF for a demonstration.
- Grow-Out to 3-inch Allowed: the sites are not closed to shellfishing, which would preclude grow out to harvest size.
- Permittability: there are no activities associated with the demonstration project that are prohibited activities under the Wetlands Protection Act, the Pleasant Bay Area of Critical Environmental Concern, Army Corps of Engineers regulations or Division of Marine Fisheries guidelines.

c. Project Evaluation

- Expected Survival: based on field evaluations, there is overall likelihood that shellfish grown at the demonstration site will live to harvest size

- Overall Likelihood of Monitoring Plan to Yield Quantified Results: based on review of map locations, watershed loading and water quality data, it is reasonable to expect that monitoring at a particular demonstration site will show statistically significant changes in water quality parameters, specifically chlorophyll a, total nitrogen and water clarity.

- Based on the MEP model, both the Nauset Harbor and Pleasant Bay System watersheds have recommended total nitrogen (TN) removal rates that are significantly higher than the expected TN removal of a shellfish demonstration project. The target nitrogen load reduction for the entire Pleasant Bay System is almost 17 million kg N/year, with each sub-watershed in the Pleasant Bay system having a lower target nitrogen removal rate than the system as a whole. Since the system circulates, it is not likely that a small uptake of nitrogen in just one sub-embayment will register a reduced TN concentration at the sentinel station in that sub-embayment, even if it is a significant percent of the nitrogen load reduction for that sub-watershed. The target nitrogen load reduction for the Nauset Harbor system is approximately 8600 kg N/year, while the Town Cove sub-embayment target load reduction is approximately 6700 kg N/year. Therefore, to quantify the nitrogen-removal of a demonstration project, monitoring plans will need to be designed to capture localized water quality improvements near the demonstration sites. This is accomplished by positioning monitoring stations upstream, instream and downstream of the demonstration site, with high spatial resolution. Sites with clearly defined upstream and downstream locations ranked highest for the criterion that monitoring plans will yield quantitative results.

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

To rank each criterion in the Site Selection Matrix, the Shellfish Technical Team assembled available data, and conducted a site visit. A ranking 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 ranking (1) was assigned if the criterion could be met fully.

- Neutral = 0 points: A neutral ranking (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 ranking (-1) was assigned if the criterion could not be met.

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

For the Permitting criteria, if a site was likely to be permitted based on the criterion being ranked it was assigned a numerical value of 1; if the site was likely to be permitted, but there were potential issues based on the criterion being ranked, it was assigned a ranking of 0; and if the site was unable to be permitted within a particular criteria, it was assigned a ranking of -1.

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

To apply this tool to each potential shellfish demonstration site, the Shellfish Technical Team held a day-long working session. At this session, the Team first reviewed and discussed all of the available information for each site: water quality data from the MEP Reports, Pleasant Bay Alliance data and reports, shellfish suitability and other GIS maps from the DMF, preliminary grain size maps from Center for Coastal Studies and notes from site visits with the harbormaster and shellfish constable. The Team then evaluated each demonstration site and ranked the criteria for each site based on this available information.

Once each site was ranked, the Team reviewed the numerical values assigned to each criterion across sites to ensure consistency. The Team also discussed whether any criterion was more important than another and determined that each criterion should be weighted equally.

The final step in site evaluations is to assign an overall rating to each site based on evaluation findings and criteria rankings. Before total criteria points were calculated and site rating assigned, the team deliberated over which sites seemed preferred for demonstrations from a qualitative and common sense perspective. Then, quantitative rankings were tabulated in the Site Selection Matrix. Results are discussed in Section 6.

6. Findings/Recommendations: Summarize Site Selection Matrix/Site Screening Results

The results of the Site Suitability ratings are as follows:

- Little Pleasant Bay Existing Grants (12 points);
- Quanset Oyster Reef (12 points);
- Pochet Oyster Reef (10 points);
- Arey's Pond Oyster Singles in Floating Bags (9 points);
- Town Cove quahog propagation (9 points);
- Mill Pond quahog propagation (9 points); and
- Lower River Oyster Singles in Floating Bags (7 points).

A maximum of fourteen (14) points is possible. Because the Team determined that all of the criteria were equally important to site selection, no one criterion impacted the overall ratings more than any other. Furthermore, this overall rating was consistent with the assessments made after deliberations but before numerical tabulations were completed.

The top two sites derived from both the Site Selection Matrix as well as Team deliberations are Little Pleasant Bay for shellfish aquaculture and Quanset Pond for an oyster reef (CHR). These two sites were also recommended by the Shellfish Constable and Harbormaster during the site visits. To demonstrate the water quality benefits as well as implementation logistics and practical densities of oyster aquaculture, working with current shellfish grant-holders seems ideal. The expertise, gear and interest already exist. The Engineering Work Plan for this option will be detailed in the subsequent TM, but generally includes working with growers to optimize shellfish harvest numbers, identify the needs of this group, and design a monitoring plan that can capture water quality impacts. A preliminary monitoring plan has already been developed for this site (Science Wares, 2015). To demonstrate an oyster reef, Quanset Pond has several advantages, including ease of access and patrol, suitable bottom and nutrients, and a reasonable expectation of monitoring yielding quantifiable results. Pochet is also a favorable location for an oyster reef demonstration but access and patrol is more difficult, and therefore this site did not rank as highly as Little Pleasant Bay and Quanset.

Arey's Pond is space-constrained, and the sediment is unsuitable to bottom planting for second year grow-out. Thus, this site does not have good replicability to other areas. Pursuing a shellfish demonstration in Town Cove or Mill Pond is not recommended because (1) oyster propagation is precluded due to excessive oyster drill population (Massachusetts Shellfish Officers Association advises against oyster propagation where drills are prevalent as a Best Management Practice) and; (2) a population study for quahogs is necessary to establish a baseline before any new propagation can be quantified. Finally, given the potential use conflicts and difficulty of monitoring yielding quantifiable results, the Lower River is the least attractive site for a demonstration.

7. References

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

Dame, R.F., Spurrier, J.D. & Wolaver, T.G. (1989). Carbon, nitrogen and phosphorus processing by an oyster reef. *Marine ecology progress series. Oldendorf*, 54(3), 249-256.

Dame, R. (1996) Ecology of Marine Bivalves: An Ecosystem Approach. CRC Press, N.Y.

Frankic, A., and Cataldo, A. (2007). Site suitability analysis for shellfish spawning sanctuaries in Wellfleet Harbor, Massachusetts, USA. Available on line: https://www.umb.edu/editor_uploads/images/centers_institutes/greenbostonharbor/FRANKICCataldo.pdf

Frankic, A. (2012). Oyster Reef Restoration Project 2012/USDA Report. Town of Wellfleet. http://www.wellfleetma.gov/sites/wellfleetma/files/file/file/wellfleet_oyster_project_and_water_quality_2012_results.pdf

Gosling, E. (2003) Bivalve Molluscs: Biology, Ecology and Culture. Fishing News Books, Oxford, UK

Jones, P.J.S. (2006) Collective action problems posed by no-take zones. Marine Policy 30: 143-156

Lorio, W.J., and Malone, S. (1994) The Cultivation of American Oysters, Crassotrea virginica SRAC Publication #432 Available online: http://srac.tamu.edu/fulllist.cfm.

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

Menzel, W. (1989) The biology, fishery and culture of quahog clams, *Mercenaria*. Clam Mariculture in North America. Manzi, J.J., and Castagna, M., editors. (Developments in Aquaculture and Fisheries Science Vol. 19). Elsevier, New York

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

Phase I: Orleans Shellfish Operations and Program Expansion Plan" Technical Memorandum (Science Wares, June, 2015)

Sellers, M.A., and Stanley, J.G. (1984) Species profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North Atlantic): American Oyster. U.S. Fish and Wildlife Service. Available online: http://www.nwrc.usgs.gov/publications/specindex.htm

Stanley, J.G., and Dewitt, R. (1983) Species profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North Atlantic): Hard Clam. U.S. Fish and Wildlife Service. Available online: http://www.nwrc.usgs.gov/publications/specindex.htm

Whetstone, J.M., Sturner, L.N., and Oesterling, M.J. (2005) Biology and Culture of the Hard Clam *Mercenaria mercenaria*. SRAC Publication #433. Available online: http://srac.tamu.edu/index.cfm?catid=22.