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Memorandum

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Subject	**Town of Orleans, MA** **Water Quality and Wastewater Planning** **Task Number 4.a.4 – Adaptive Management Plan** **Technical Memorandum for Non-Traditional Technology Performance Analysis**
Project Number	60476644
From	Thomas Parece, P.E., AECOM Project Manager
Date	03/25/16

1. Introduction

The purpose of this Technical Memorandum is to present a systematic program for monitoring three non-traditional technologies: Shellfish, Floating Constructed Wetlands (FCW), and Permeable Reactive Barriers (PRBs). Non-traditional technologies are also referred to as non-traditional technologies in the Cape Cod Commission Section 208 Plan Update, and the Orleans Consensus Plan and related documents.

There are several different aspects of non-traditional demonstration projects to be quantified through monitoring, such as:

- Nitrogen-removal;
- Changes in other water quality parameters such as turbidity and dissolved oxygen;
- Changes in coupled nitrification-denitrification in underlying and nearby sediments;
- Project logistics during installation, operation and maintenance;
- Actual capital, operation and maintenance costs;
- Survival and growth for shellfish and standing macrophyte biomass (for FCW);
- Groundwater characteristics (for PRB); and
- Attributes of carbon substrate such as distribution, and performance (for PRB).

To enable quantification as well as evaluation of these parameters for shellfish and FCW, monitoring plans have been tailored to specific project locations, and are based on consideration of site features such as water circulation and residence time, expected nitrogen uptake relative to current nitrogen load and the size of the demonstration. The goal of the monitoring plan for a PRB is to validate patterns of groundwater flow and nitrate flux, establish patterns of substrate distribution and establish the level of nitrate removal that is possible at the selected location.

2. Introduction: Demonstration Project Descriptions

a. Permeable Reactive Barrier (PRB) Project Description

Two Technical Memoranda that detail the planning and design for a PRB demonstration in Orleans have been prepared:

- Site Characterization and Evaluation for Permeable Reactive Barriers (PRB-TM-1); and
- Draft Preliminary Engineering Work Plan for Permeable Reactive Barriers (PRB-TM-2).

Based on detailed evaluations described in PRB-TM-1, a preferred Demonstration Test site at Eldridge Park was selected based on key location features, available data, and the ability to provide results representative of other areas in the Town. Two additional potential demonstration sites, including the Town Landfill and Gibson Road at Asa's Landing were identified as test site options that may also be implemented with the preferred site, given sufficient funding. The landfill demonstration location is seen as highly advantageous, close in preference to the Eldredge Park location, and ideally would be implemented along with Eldredge Park.

The Town-owned Eldredge Park Demonstration Test site is located in the parking lot area between the playing fields off Eldredge Parkway. This demonstration location supports full scale PRBs that may be located in Eldredge Park, along South Orleans Road, Tonset Road, and Main Street or some combination of these options. PRBs at one or more of these locations would be designed to reduce nitrogen loading to Town Cove. Several groundwater monitoring wells were installed for a separate investigation at the Police Station (less than 500 feet east), and the depth to groundwater is approximately 30 feet using these wells. A significant mass flux of nitrate in groundwater is expected at the preferred Demonstration Test location (estimated 710 kg/yr as calculated with WatershedMVP), and the groundwater flows from this area toward Town Cove to the northeast. The parking lot area provides sufficient room for both the layout of the PRB and upgradient and downgradient monitoring wells.

As detailed in PRB-TM-2, the first step in implementing a PRB in Orleans is to conduct Demonstration Tests. The Demonstration Tests will provide data to assess the effectiveness and applicability of PRBs as a treatment alternative for the Town. It is expected that the tests will determine the level of nitrate removal that can be achieved with PRBs and provide the data that is needed to prepare a full scale design. The Demonstration Tests will be evaluated by the following performance objectives:

- Achieve satisfactory distribution of the carbon substrate solution into the subsurface;
- Establish and maintain necessary anaerobic (reducing) and groundwater flow conditions in the subsurface throughout the targeted treatment area;
- Demonstrate reduced nitrate concentrations and flux in groundwater through monitoring to extrapolate to reduction targets for full scale implementation (total maximum daily load [TMDL]);

- Demonstrate performance, compliance monitoring, and assessment of treated water quality, including potential secondary water quality affects, through groundwater monitoring program;

- Evaluate time frame for technology performance; and

- Obtain data for engineering evaluations and to optimize full scale design and implementation.

b. Floating Constructed Wetland (FCW) Project Description

Two Technical Memoranda that detail the planning and design for a FCW demonstration in Orleans have been prepared:

- Site Characterization and Evaluation for Floating Constructed Wetlands (FCW-TM-1); and

- Floating Constructed Wetland NT Demonstration Project Work Plan (FCW-TM-2).

Kescayo-Gansett (Lonnie's Pond) was selected as the preferred demonstration location. As detailed in FCW-TM-2, to most effectively capture the nitrogen-laden surface water entering Lonnie's Pond, it was determined that the FCW units should be located directly in front of the two distinct discharge areas: the drainage pipe located in the northwest section of the pond, just north of the public access ramp; and the herring run, located in the southwest section of the pond, south of the public access ramp. In addition, to further characterize differences in water quality between the freshwater entering the pond and the salt water entering the pond, it was determined that the FCW units should also be located near the mouth of the tidal channel that connects the pond with The River.

Figure 1 shows a schematic and installation of a FCW project. System components include:

- **Floating modules** will be constructed out of 4-inch welded HPDE pipe. Each rectangular module will be approximately 6 feet by 12.5 feet and be divided into 2 sections. Mesh (1.5-inch hex HDPE mesh) will be welded to the underside of each module. The modules and islands will be custom units built for this demonstration project. Each module will also have welded flanges so they can be bolted together. Nine modules will be bolted together to form a cluster. Each cluster will be anchored using helical anchors and will also be tied to other clusters with ½-inch double braided polyester rope.

- Each FCW module will be covered in **coir blankets**. Coir is a natural fiber extracted from the husk of coconuts and commonly used in household and horticulture products. Coir is 100 percent biodegradable, yet strong and durable enough to support plants during the few years of establishment. These blankets have 0.75-inch x 0.75-inch openings to allow for planting plugs without cutting the blanket.

- **Anchoring** of the islands will be achieved by using helical embedment anchors driven into the seabed. The final type and number of anchors and mooring lines needed will be evaluated as the design progresses, but at the current time it is estimated for purposes of this work plan that four anchors and four mooring cables will be required per nine-module cluster. Helical anchors provide benefits including high pull strength, and easy installation and removal.

- **Mooring lines** for the islands will utilize a combination of galvanized steel cable and elastic mooring units. The combination will allow for continual tension of the mooring lines for minimal impact to the benthic environment, even at low tide, while also allowing the structure to move with the changing tides. Elastic mooring will also reduce floating island movement by keeping the island close to its constructed footprint while also dampening the movement of the individual units.

- The anchor, mooring and connection systems will be designed to resist forces approaching from all directions. The mooring and unit-to-unit connections are designed with redundancy to prevent the floating islands from becoming detached and free-floating around the pond. Each FCW unit will be secured to the seabed by one line and secured internally with redundant unit-to-unit connections.

- **Plant** type initially will be *Spartina alterniflora*, which will be obtained from local sources, to be approved by the Town of Orleans. *S. alterniflora* was determined to be the most suitable for the initial planting due to its proven ability to quickly become established in the first growing season in salt waters. Plants will be placed on one-foot centers, for a total of 72 plants per unit. The roots of the *S alterniflora* will grow from the surface through the porous matrix to the subaquatic environment, and will thus be available to the subaqueous community as habitat. After the first growing season, a diversity of plants can be added to the islands at the beginning of the growing season.

- **Waterfowl fencing** will be placed around each unit to deter use of the mats by waterfowl and shorebirds. Fencing will include posts along the edges of the islands, and string and flagging attached to the posts that criss-cross the islands. The waterfowl fencing will be removed after the first growing season.

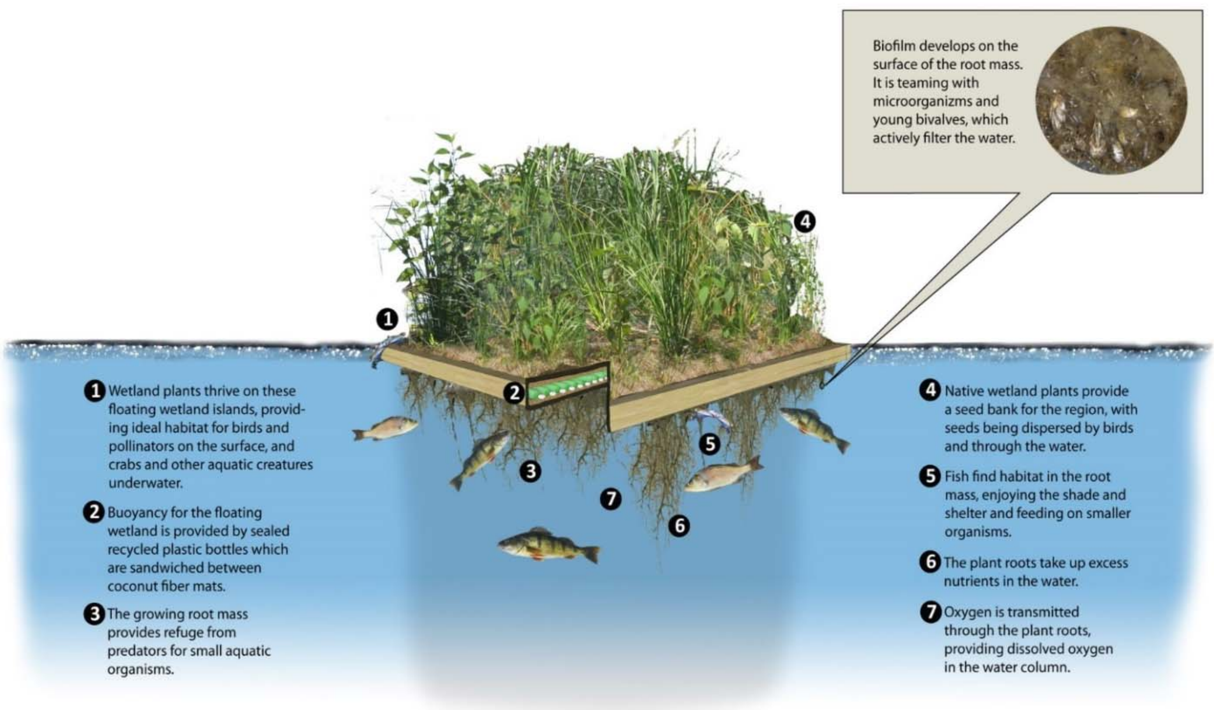

Figure 1: FCW Schematic and Installation

c. Shellfish Project Descriptions

Two Technical Memoranda that detail the planning and design for a shellfish demonstration in Orleans have been prepared:

- Site Characterization and Evaluation for Aquaculture/Shellfish Propagation (SHEL-TM-1); and
- Preliminary Engineering Design and Work Plan for Preferred Site(s) (SHEL-TM-2).

The following four demonstration projects were described in SHEL-TM-2:

- Quahog Population Study in Town Cove and Pleasant Bay
- Oyster Bed in Trays in a Terminal Pond of Pleasant Bay
- Quanset Oyster Bed with Bottom Planting
- Enhanced Aquaculture in Pleasant Bay and Town Cove

1) Baseline Quahog Population and Propagation Planning

Key reasons for this demonstration project:

- Suitable bottom in these estuaries is ideal for enhanced quahog planting;
- Need to establish a baseline population count to quantify success of future propagation efforts, and determine capacity for additional quahogs; and
- Populations of quahogs and other species will be counted in areas historically planted as part of municipal propagation.

In Town Cove and parts of Pleasant Bay, expansion of municipal quahog propagation is recommended to establish maximum practical densities that can be grown and harvested in these areas, and to allow water quality changes to be correlated to numbers of new quahogs added to these systems. Historically, quahogs have been grown successfully through the Town's propagation program, and there is suitable bottom in both Town Cove and Pleasant Bay for increased quahog planting. Based on site reviews, it was found that there are existing populations of quahogs throughout Town Cove and Pleasant Bay. Therefore, a quahog demonstration should only be pursued after a bassline population is established. This will provide an estimate of current quahog densities in specific areas where additional quahogs would be planted as part of a demonstration.

Determining current populations before additional quahogs are added to these waterbodies is an important first step in evaluating survival, growth, and the impacts of additional quahogs on water and sediment quality. This survey is also critical to determining how many additional quahogs should be planted. Once the baseline population is established, the specific quantities and sizes of additional quahogs will be recommended as part of an expanded quahog propagation program for certain areas in Town Cove and Pleasant Bay.

2) Oyster Bed Installations in Terminal Ponds and Quanset

Key reasons for a demonstration project in a terminal pond:

- Water quality most degraded in terminal ponds;
- Oyster beds have higher density than gear-based systems per unit area, and create diverse habitats that provide ecosystems services;
- Demonstration needed to determine whether oyster beds can uptake nitrogen and make a measurable improvement in water quality in terminal ponds;
- Terminal ponds have fine-grained, soft sediment that is often anoxic, which precludes bottom-planting;
- Oyster beds will be maintained in trays that are kept off-bottom with footings; and
- Predation and disease may be minimized by growing remote set (spat-on-shell) in covered trays.

Key reasons for a demonstration project in Quanset:

- Oyster beds are often created by growing remote set (spat-on-shell) in gear for a period of time, then bottom-planting on suitable substrate;
- Oyster beds have higher density that gear-based systems per unit area, and create diverse habitats that provide ecosystems services;
- Demonstration needed to determine whether oyster beds can become a self-sustaining habitat in Pleasant Bay; and
- Predation and disease must be considered for this growing option.

The oyster bed demonstration projects involve growing remote set and planting it in suitable areas, resulting in bed-like grow-out under the diverse environmental conditions experienced over the course of a typical Pleasant Bay growing season. Remote set is a firm substrate, or cultch, such as hard clam shells, with oyster spat attached. Eastern oyster larvae (Crassostrea virginica) produced in a hatchery can be "set" on cultch after a larval stage spent feeding in the water column. This spat can also be induced to set on microscopic shell fragments to produce seemingly unattached "singles". When attached to a substrate, this spat, invisible to the naked eye, is often called "spat-on-shell" or "remote set". The waters of Pleasant Bay do not have a naturally-occurring oyster population that could spawn. To establish an oyster bed in areas where there is no natural set, remote set can be used to introduce oysters into the growing environment.

The methodology proposed for establishing an oyster bed off-bottom in trays in a terminal pond of Pleasant Bay is modeled after a successful program in Mashpee, MA. Candidate ponds include Meetinghouse Pond, Kescayo-Gansett (Lonnie's) Pond, Arey's Pond, and sections of the River and Namequoit. Paw Wah Pond is also a possibility, but a relay out of this area will be required once the oysters are large enough to be harvested because this pond is currently closed to shellfishing. These ponds will be evaluated with the town to determine the preferred site. The technique for establishing an oyster bed in the Quanset Pond area is similar to techniques used throughout Cape Cod, and recently implemented successfully in West Falmouth Harbor, MA. Both techniques begin with installing remote set in trays and/or floating bags for an initial growing period. In terminal ponds, oysters remain in trays that are held off-bottom because the bottom is not suitable for planting. Harvest occurs by bringing trays to shore and opening this area to recreational harvest.

In the Quanset area, remote set is able to be bottom planted after approximately eight weeks. The remote set will likely be planted under the bags and trays in which they were initially grown. The significant benefit of planting remote set after a maturation period is that it allows the oyster spat to mature in a protected environment, thus reducing predation and mortality. Planting remote set when oysters have reached over 1.5 inches (38 mm) in size also reduces mortality caused by siltation. Harvest occurs by opening this area to recreational harvest.

Growing out remote set in both trays as well as floating bags with bottom-planting will enable an evaluation of the growth and survival rates of each technique. Moreover, evaluating the potential for bottom-planting oyster remote set at Quanset will help determine the feasibility of expanding oyster beds in other part of Pleasant Bay where there is suitable substrate, such as areas along the Upper and Lower River, Namequoit, and Pochet. Maintaining oyster beds in off-bottom trays is a technique that is replicable to any area in Orleans where the bottom is not a suitable substrate for direct planting. Meetinghouse Pond, Kescayo-Gansett (Lonnie's) Pond, Arey's Pond, Paw Wah and sections of the River and Namequoit are all suitable areas for remote set in off-bottom trays.

3) Shellfish Aquaculture

Key reasons for a shellfish aquaculture demonstration project:

- In Orleans, there are twelve aquaculture leases in Pleasant Bay and one in Town Cove. Eastham has approximately thirteen leases in Town Cove;
- Aquaculture improvements would increase the number of shellfish being grown in Orleans;
- Meaningful dialogue with growers is needed to build an understanding of the practical extent to which shellfish aquaculture can contribute to the town's water quality goals;
- Working with growers will also help define the needs of this group relative to the town's numerical goals for shellfish; and
- Explore possibility of additional leases in Town Cove.

The demonstration methodology proposed for Little Pleasant Bay involves working with the growers on the town's existing private shellfish leases. There are currently 12 leases in Pleasant Bay with an average size of 1.75 acres. Typically, single oysters are raised from seed to harvest size in trays, bags and cages. Seed is sometimes purchased at a size large enough to install directly in gear. Smaller seed requires grow-out in an on-shore upweller. In total, growers are harvesting approximately 700,000 oysters annually from these leases in Pleasant Bay. Harvesting occurs year-round. To avoid ice damage over the winter, shellfish are submerged to deeper depths or are bottom-planted.

Working with growers can create opportunities to demonstrate the water quality benefits as well as implementation logistics and practical densities of oyster aquaculture. Part of the reason for conducting demonstrations is to learn site-specific factors and adjust farming practices accordingly. Local growers have decades of field experience working in Pleasant Bay and Town Cove, and have learned how to manage and operate within the varying conditions in this location. They have evolved systems based on trial and error for anticipating weather and other events that impact shellfish survival. Successful farming requires local knowledge; implementation techniques need to be tailored to a given site. This project generally includes working with growers to optimize shellfish harvest numbers, by identifying the needs of this group to increase numbers grown, and designing a monitoring plan that can capture water quality impacts. A preliminary monitoring plan has already been developed for this site and is contained in the "Phase I: Orleans Shellfish Operations and Program Expansion Plan" Technical Memorandum dated June, 2015.

The expansion of private leases for oyster aquaculture in certain areas of Town Cove is also an important option to pursue. Oyster aquaculture in gear, off the bottom would be the only method of growing in this area due to the oyster drill population. The expansion of private grants requires several permitting steps beginning with a recommendation from the Board of Selectmen to the MA Division of Marine Fisheries. A study of the feasibility of expanding private aquaculture leases is needed to assess the Town's interest in this approach for shellfish aquaculture in Town Cove.

This demonstration will build on these established growing methods, and includes three components:

- Discussions with growers to evaluate current growing practices, and opportunities for improving operations;
- Working with growers to establish a total number of shellfish that can be grown and harvested annually for all leases in aggregate; and
- Evaluate areas in Town Cove for expanding shellfish leases.

3. Monitoring Plans

In this section, monitoring programs for each non-traditional technology are presented. Figure 2 shows the proposed locations for a PRB near Eldredge Park, a FCW in Lonnie's Pond and shellfish demonstrations in several locations. (insert map here).

a. PRB Demonstration Monitoring for Initial Characterization and Demonstration Planning

As detailed in PRB-TM-2, AECOM is currently performing initial subsurface site characterizations at representative sites in Orleans. These hydrogeological investigations provide critical information to support the final design of PRB demonstration tests. At four locations, including 82 Main St, Snow Library, the police station and the landfill, data from soil borings have been advanced to record soil classification with depth, and multi-level groundwater monitoring wells have been installed.

Previously existing monitoring wells at selected locations are also being included in this investigation. Monitoring well locations will be surveyed for elevation and location, and the depth to groundwater will be measured and mapped to evaluate groundwater flow direction. Groundwater samples are being collected for laboratory analyses to assess groundwater quality related to PRB design and concentrations of nitrogen species. Each new well location has two or three discrete screened intervals to collect groundwater samples at different depths. Groundwater velocity at each site will be estimated using observed hydraulic gradient and soil conditions. Location and depth of the salt water interface will be identified where present within the investigated depth. Groundwater sampling results and related calculations will be available in March 2016 and will be used to inform demonstration test design.

The approximate locations of the proposed PRB demonstrations are shown on Figures 3 and 4 for Eldredge Park and the landfill, respectively. Demonstration test PRB lengths are 200 feet at Eldredge Park and 50 feet at the Landfill site, and include one line of injection points spaced 10 feet apart. Demonstration test locations are proposed to be shorter distances than full scale PRBs to assess construction/implementation and allow adequate monitoring of groundwater conditions in the vicinity of the PRBs as an initial validation of performance. For the demonstration test PRBs, a vertical treatment interval is anticipated from the top of the groundwater table to approximately 40 feet into the saturated soils. The total depth below land surface will also depend on the depth to groundwater at the location. Multi-level groundwater sampling events conducted on Cape Cod have identified bands of groundwater containing nitrate concentrations 25 to 40 feet thick (MT Environmental, 2015). However, the initial subsurface groundwater investigations currently underway will provide appropriate data to more accurately define the necessary vertical depth of injected Emulsified Vegetable Oils (EVO) for the two proposed PRB demonstration locations.

Installing and monitoring a demonstration PRB involves a phased approach. Phase I includes baseline groundwater monitoring, and an initial injection test. Using the results of Phase I monitoring, a final design can be prepared. Phase II involves installing a PRB demonstration based on this final design, and monitoring performance over a period of three years. These activities involve:

Phase I: Baseline Groundwater Monitoring - Additional monitoring wells will be installed. Monitoring wells will be surveyed, and groundwater elevations will be measured. One round of sampling for groundwater collection will be performed with samples sent to a laboratory for analysis of parameters identified in Table 1. Well installation is anticipated to occur over a period of two weeks. Sampling groundwater wells will be completed over a period of one to two weeks.

Phase I: Initial Injection Test - Injections of EVO will be conducted at a small number of injection points at one or both of the two proposed sites (Eldredge Park and/or landfill). Injection tests will be conducted over approximately one week. Groundwater monitoring will be conducted for approximately four to six weeks following the initial injection.

Final Design - Based on the results of the baseline groundwater monitoring and observations of the initial injection test the 100 percent design document for the demonstration test PRBs will be completed. It is expected that the final design will be completed three to four months after the initial injection test based on site-specific observations and if any major process changes are required from preliminary design.

Phase II: Demonstration Test Injection - Drilling and injection subcontractor(s) will mobilize for implementing the injections for the Demonstration Test PRBs. It is anticipated that field work will occur over a period of one to two months based on AECOM experience injection on similar sites.

Phase II: Demonstration Test Performance Monitoring - Following injection, groundwater sampling to evaluate performance of the PRBs will be conducted. It is recommended to collect quarterly samples for a period of three years. Periodic reporting would be conducted to share results and observations with the Town, regulatory agencies, and the public.

PRB Demonstration Monitoring for Performance

The network of monitoring wells for performance monitoring is presented in Figures 3 and 4 for the Eldredge Park and landfill PRBs, respectively, and are the same figures presented in PRB-TM-2 as Figures 7-1, and 7-2. Monitoring wells are located upgradient and downgradient of the PRB to evaluate changes to nitrate and groundwater quality. Monitoring wells downgradient are positioned at various distances away from the PRB to assess distance of emulsion travel, extent of reducing conditions for denitrification away from the PRB, potential for metals mobilization, and groundwater flow velocity. Monitoring wells cross-gradient of the PRBs will also be included, and hydraulic conductivity will be estimated in the cross-gradient and select downgradient monitoring wells to evaluate if there is any observed reduction in aquifer permeability as a result of the injection of EVO.

Performance monitoring of the PRB demonstration test will assess three key parameters, including nitrate transformation, concentrations of other key indicators, and spatial distribution of the injected reagents. Primary objectives of performance monitoring sampling is to:

- Demonstrate reduction in nitrate concentrations in groundwater in monitoring wells compared to baseline samples and/or wells upgradient of the PRB;
- Identify distance traveled by EVO emulsion;
- Identify extent of generated reducing conditions;
- Evaluate potential for reduction in aquifer permeability as a result of EVO application;
- Evaluate persistence of EVO emulsion and anaerobic conditions favorable for denitrifying bacteria after PRB installation;
- Assess changes in groundwater monitoring parameters as a result of the PRB; and
- Determine whether temporary mobilization of some metals native to the aquifer material is occurring.

All performance monitoring wells will be constructed of two-inch schedule-40 PVC, with proposed screened intervals as shown in Appendix A for Eldredge Park and the landfill (Tables 7-1 and 7-2 of PRB TM-2). New monitoring wells are anticipated to be installed using direct-push drill rigs, as this method was used to install monitoring wells near the PRB locations for characterization and was determined to be a cost-effective means of installing wells for collecting representative groundwater samples. Groundwater samples will be collected using a peristaltic pump, bladder pump or whale pump. Groundwater quality parameters will be measured in the field (pH, oxidation reduction potential (ORP), dissolved oxygen (DO), specific conductivity, temperature, turbidity), with particular attention to ORP (mV) and DO (mg/L) which will be used to evaluate the generation and distribution of reducing conditions. Samples will be collected after field water quality parameters stabilize, or after 30 minutes of purging if parameters do not stabilize sooner.

Groundwater samples will be collected prior to initiation of in-situ treatment to provide a comparative baseline to evaluate performance of the demonstration test. Baseline groundwater samples will be analyzed to determine pre-treatment concentrations of nitrate and other indicator parameters whose change will be indicative of the impact of Demonstration Test treatment processes.

In addition to sampling the installed wells, a synoptic water level event will be conducted after additional monitoring wells are installed but prior to the start of the demonstration test injections to further assess groundwater direction and gradient. The first baseline sampling event would be completed prior to the initial injection test. Laboratory analysis of select metals will also be conducted as part of performance monitoring in select wells.

Following completion of injections for the full demonstration tests, it is anticipated that groundwater sampling would be performed quarterly for a period of three years. This program includes collection of groundwater samples from both existing monitoring wells (used for initial characterizations) as well as the installation of additional monitoring wells.

Table 1: Summary of Analyses for Groundwater Performance Evaluation

Parameter	Relevance to PRB Demonstration Test
Nitrate	Primary groundwater compound targeted for treatment.
Nitrite	Intermediate nitrogen species from the aerobic nitrification of ammonia to nitrate.
Ammonia	Reduced inorganic nitrogen species that occurs in proximity of leach fields and landfills.
Total Nitrogen	Analyses provides a summation of all organic and inorganic nitrogen species in groundwater as a result of leachfields and landfill.
CENSUS-DNA (Denitrifying Bacteria)	Analyses quantify relative abundance of denitrifying bacteria.
Metals (Fe, Mn, As)	Mobility of metals can be impacted by groundwater geochemistry changes, notably pH and ORP.
DOC	Dissolved Organic Carbon as food source for denitrifying bacteria
Sulfate	Sulfate will decrease with generation of sufficiently anaerobic conditions favorable for sulfate-reducing bacteria.
pH	Denitrification optimal pH (6.0 and 8.5). Groundwater pH can decrease as a result of fermentation of injected carbon substrates.
ORP	Oxidation-Reduction potential will decrease with generation of reducing conditions following injection of carbon substrate.
Chloride	Chloride concentrations are higher in salt water, and higher concentrations would indicate influence of salt water intrusion.
Alkalinity	Denitrification reactions generate alkalinity (3.57 mg of $CaCO_3$ for each mg of nitrate reduced).
Boron	Boron is present in laundry detergents and is an indicator of groundwater flow emanating from Soil Absorption Systems.

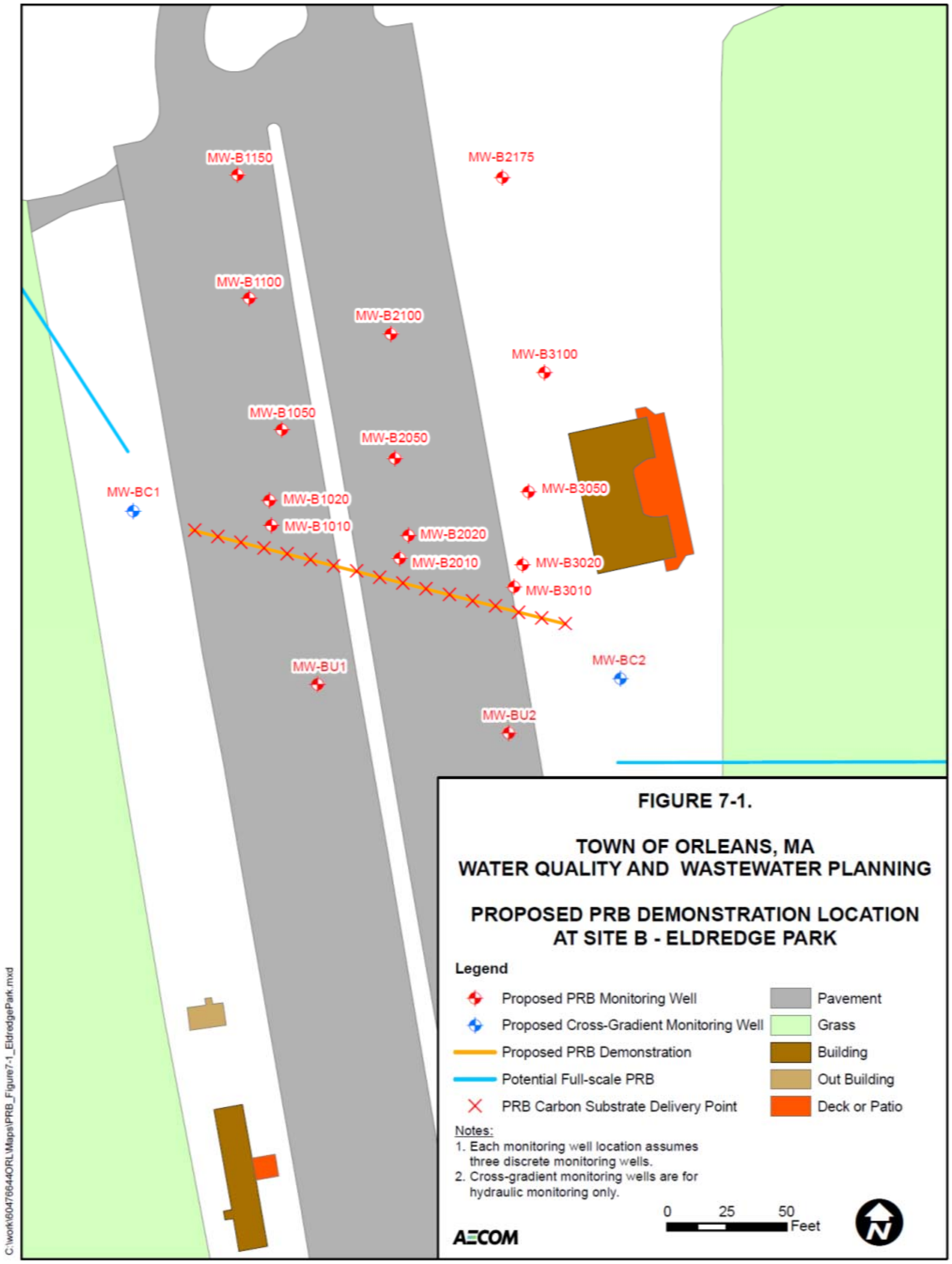

Figure 3: Eldredge Park Monitoring Wells and PRB Location

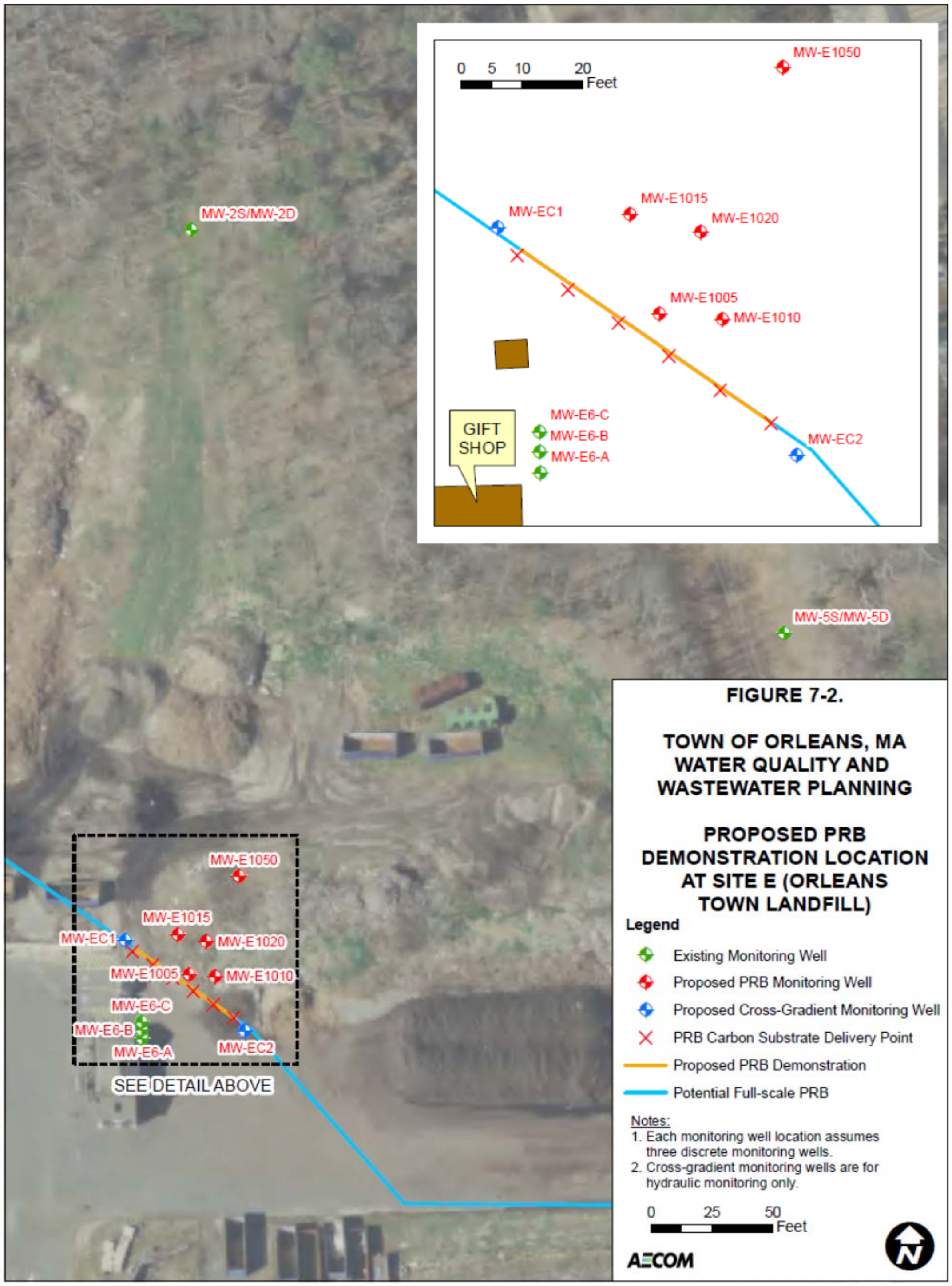

Figure 4: Landfill Monitoring Wells and PRB Location

b. Floating Constructed Wetlands Monitoring

The specific objective of this study is to evaluate the effectiveness of an array of FCW deployed in Lonnie's Pond to reduce nutrients, especially nitrogen. For this evaluation, the focus of the monitoring will include in situ water quality sampling as well as assessments of standing macrophyte dry weight biomass and nutrient uptake performance. The data collected for the Lonnie's Pond FCW will be compared to other performance data on estuarine floating wetlands in Baltimore Harbor and from other natural marshes that can provide reference conditions and an understanding of relative performance. Additionally, small round samples of FCW material "pucks" will be attached to the undersides of the FCW. A subset will be removed seasonally to collect data on epiphyte biofilm establishment and colonization by macro/micro invertebrates.

A determination of the nitrogen and phosphorus uptake rates by the epiphyte biofilm community in a controlled lab setting will be made. Seasonal measurements of redoximorphic conditions will be made of each island to determine if the conditions exist for denitrification. A calculation of the combination of the macrophyte biomass and epiphyte biofilm nutrient absorption and uptake will be made and compared to the data collected on seasonal landside water and nutrient inputs and seasonal tidal flux of water and nutrient loading in the lagoon.

1) In-Situ Water Quality Analysis

Water quality will be sampled in three ways: using continuous dataloggers; using a hand-held probe to collect discrete readings; and using grab samples that are then sent to a lab for analysis.

- Dataloggers: Water quality and current data will be collected throughout the growing season in fifteen minute intervals using YSI 6600V2 continuous data sondes. Continuous water quality parameters will include temperature, DO, turbidity, chlorophyll and salinity. The sondes will be deployed on either side (landward and seaward) of the four FCW systems, for a total of eight sondes. The data will be collected to determine if there are measurable water quality differences on either side of the FCWs.

- Discrete and Grab Samples: Discrete water quality measurements and grab samples will be taken at weekly intervals during the growing season (April 15 thru September 30) and once per month in the off seasons (October 1 thru April 14).

- Discrete onsite parameters will be measured using a hand-held YSI 556 MPS probe, and will be taken on the landward and seaward sides at each of the four FCWs at the same level in the water column during each monitoring event for the following parameters: temperature, conductivity, salinity, DO, and pH.

- Paired grab samples will be taken on the landward and seaward sides at each of the four FCW systems at the same level in the water column during each monitoring event, and will then be sent to a qualified lab for analysis of the following constituents: N02 and N03, total N, total P, TKN, TSS, NH4 and chlorophyll a.

In addition to the growing season and non-growing season sampling, once each season throughout the year a minimum of three per baseflow water quality samples will be taken for nutrient and physical chemical measurements at each inflow, as well as a minimum of three stormflow samples.

Also, once each season throughout the year, a diurnal water quality sampling regime will be employed at the tidal inlet/outlet to the lagoon collecting preserved samples and measuring the same physical parameters with a deployed datalogger every fifteen minutes and collecting nutrient data every three hours over the diurnal to determine physical/chemical, nutrient and water volume flux. Volumes of water flooding and ebbing to and from the lagoon will be calculated by utilizing recent bathymetric survey data and tidal amplitude from continuous datalogging levelloggers.

2) Lab Analysis

Aboveground biomass of vegetation on the FCW will be harvested at the end of the growing season after a full year of establishment and sorted into species. Plant biomass will be air-dried and sub-sampled. These sub-samples will be oven-dried at 70 degrees C for 24 hours and weighed. Additional sub-samples will be combined in an ashing oven in the lab to determine the ash-free dry weight. The data will be used to determine the dry weight aboveground biomass and, combined with seasonal diurnal curve measurements, an estimate of the net primary production of the wetland in relation to overall community metabolism. Carbon, nitrogen and phosphorus along with micronutrients in the biomass of each species will be assessed by using standard methods to evaluate nutrient uptake performance by the marsh community. Thus, total mass of nutrients in the aboveground biomass will be estimated by multiplying nutrient content percentage by the biomass.

Biofilm uptake analysis will be employed by deploying an array of pucks made of the same FCW material, approximately 100 mm in diameter and 15 mm thick weighing on average 3.5 to 4.0 grams. Six pucks each will be constructed and evenly spaced and attached to the FCW unit. Each floating wetland will have one rack attached. A similar number of racks will be attached to nearby docks and/or floats as control conditions. Seasonally, a rack will be randomly selected from one FCW and one control site with two pucks randomly selected from each for analysis. Each of the pucks will be broken into 22 1cm2 sections. Two squares are randomly selected for species counts. Each square will be observed under a stereoscope and organisms identified and counted.

A study will be conducted to determine how quickly the biofilm on the puck would uptake additional nutrients when added to their environment. Six, 2.0 liter volumes of salt water will be created to replicate the seasonal salinity and nutrient content of Lonnie's Pond water. Six control and six experimental pucks will be obtained from the lagoon and placed in the experimental tanks. Nutrient levels will be tested every fifteen minutes for one hour, and then every thirty minutes for the second and third hours using a colorimeter.

3) Plant Community Structure Evaluation

Comparisons of the original planting plan with the final plant community structure will be made to assess self-organization of the marsh system over the growing season. The contribution of volunteer species that were not in the original planting plan will be assessed. Data on species composition, biomass and nutrient content will be gathered on a reference estuarine FCW in the Baltimore area for comparison with referenced data from local natural marshes.

4) Maintenance Requirements

Visual inspection of the FCWs will occur on a monthly basis. The main purpose of the maintenance inspections will be to confirm that project integrity is maintained and to document any changes to the units or the surrounding area. Maintenance activities will include the following:

- Inspection to confirm integrity of all submerged hardware and anchoring, and above water tethering and waterfowl fencing;
- Health of plants, and replanting where necessary;
- Removal of man-made and natural debris; and
- Periodic inspection for signs of degradation of base material, mechanical (tearing), waterfowl use, or UV damage (discoloration).

c. Shellfish Demonstration Performance Monitoring Program

The purpose of implementing shellfish demonstrations in Orleans is to determine the extent to which shellfish can be grown to achieve water quality improvement goals as well as compliance with regulatory standards. Monitoring of both ecological parameters as well as implementation success will provide information that is needed for this water quality improvement planning and decision making. As part of implementing a comprehensive Performance Monitoring Program, a Quality Assurance Policy Plan (QAPP) is recommended. Both the UMASS Dartmouth's School for Marine Science and Technology (SMAST) and the Center for Coastal Studies have a QAPP for water quality and benthic denitrification and infauna sampling. Either QAPP is appropriate and should be followed. In addition, for other aspects of field and analytical work, an additional project specific QAPP should be developed.

Proposed demonstrations are in the Pleasant Bay and Nauset Harbor watersheds. Through the Pleasant Bay Alliance's Monitoring Program, baseline data exists in Meetinghouse Pond, Arey's Pond, Keyscayo-Gansett (Lonnie's) Pond, and Quanset Pond. While there are monitoring stations near the existing shellfish grants in Little Pleasant Bay, the first step for this demonstration is to establish baseline conditions directly within the shellfish grant areas.

It is recommended that for implementing shellfish projects in Nauset Harbor (Town Cove and Mill Pond) the first step is to reinstate water quality monitoring at the WMO-25 to WMO-35 monitoring stations. This is needed to establish pre-installation baseline conditions. Monitoring at these stations, except for the three Sentinel Stations (WMO-25, WMO-24, and WMO-38) has not been reported since 2005 and conduct a standing stock assessment for quahog populations in Town Cove and Pleasant Bay.

1) In-Situ Water Quality Monitoring

To quantify any water quality changes that result from the demonstration projects, bi-weekly sampling from May – September should include the following parameters at both water surface and bottom locations within the sampling stations: Total Nitrogen (TN), nitrate + nitrite, ammonia, dissolved organic nitrogen (DON), dissolved inorganic nitrogen (DIN), particulate organic nitrogen (PON), Temperature, Chlorophyll *a*, Pheophytin *a*, Orthophosphate, Salinity, Dissolved oxygen (DO), and Transparency (Secchi depth). Continuous monitoring of Chlorophyll *a*, DO and transparency is recommended. The following table shows the frequency and timing of sampling that should occur for water quality monitoring. (add station names/numbers once finalized)

	May 1 - 15	May 16 - 31	Jun 1 - 15	Jun 16 - 30	Jul 1 - 15	Jul 16 - 31	Aug 1 - 15	Aug 16 - 31	Sept 1 - 15	Sept 16 - 30	Oct 1 - 15	TOTAL SAMPLES Surface and Bottom
STATION ID												
Demo-1	2	2	2	2	2	2	2	2	2	2	2	22
Demo-2	2	2	2	2	2	2	2	2	2	2	2	22
Demo-3	2	2	2	2	2	2	2	2	2	2	2	22
QA/QC (10%)												
Total Samples												

2) Measuring denitrification rates associated with oyster aquaculture and oyster bed building

Also recommended for analysis is enhanced sediment denitrification, caused by oyster aquaculture and oyster bed development. This analysis includes collecting sediment core samples, and incubating them under in situ conditions during the period of maximum denitrification rates in the summer interval (July-September). Time series measurements of total dissolved nitrogen, nitrate+nitrite, ammonium and ortho-phosphate should be made on each incubated core sample. The rate of oxygen uptake should also be measured in order to: (1) rank sediments relative to organic matter deposition rates and (2) develop a general nitrogen model for oyster impact to the nitrogen cycle in the sediments.

Assays should be performed on cores distributed throughout the oyster aquaculture area (directly under the oyster aquaculture rafts and along a 100m transect extending south. The results should show any spatial pattern and rate of nutrient exchange between the sediments and water column, and whether these rates are affected by the cultivation of oysters in Quanset Pond and Little Pleasant Bay.

Excess nitrogen gas (N_2) is measured using membrane-inlet mass spectrometry (MIMS). N_2 produced by denitrification is precisely detected by analysis of its ratio with the inert gas Argon. Water samples should be collected and stored to prevent gas exchange or bubble formation. In the laboratory, sample water is pumped at ml/min rates through a gas permeable membrane in order to extract gas into the mass spectrometer inlet.

3) Demonstration Projects

a) Baseline Quahog Population and Propagation Planning

This program is implemented by conducting a baseline population survey for a number of areas in Town Cove and Pleasant Bay. Appendix A includes a list of the areas that have been historically planted in Orleans. Three, ten meter transects should be defined through the two ends and center of selected quahog planting areas. For each transect, five separate square meter sample areas should be surveyed for all organisms. Quahog numbers will then be used as the baseline density. A detailed scope of work will be developed prior to soliciting bids for professional services to conduct this survey.

INSERT MAP FROM TOWN HERE

b) Water Quality Monitoring Locations: Terminal Pond Demonstration

A map and monitoring stations (similar to the ones provided below for Quanset and Little Pleasant Bay) will be provided, once the specific terminal pond of the oyster bed in trays is selected.

Year 1 monitoring will establish baseline conditions, while oyster growth viability testing is underway. Final reporting for Year 1 will include:

- Baseline water quality conditions;
- Size classes by length for one year of growth;
- Tray area covered per bag of remote set;
- Review of viability of site for shellfish growth;
- Assessment of operation and maintenance requirements of trays;
- Useful modifications to tray design;
- Recommendations on the type of shellfish grown and whether there should be a mix of species;
- Assessment of abutter compatibility and use conflicts.

c) Water Quality Monitoring Locations: Quanset Pond Demonstration

To establish whether there is a shellfish impact on water quality, ten (10) sampling stations are proposed. As shown in Figure 5, these stations are located above, within and directly below the proposed oyster reef two-acre growing area (shown as blue rectangle), enabling direct analysis of the water as it flows across the growing areas. In addition, a benthic infaunal survey of the growing area should be conducted to establish a baseline benthic macrofauna density and species diversity to enable future quantification of the overall impact to habitat through creation of the oyster reef.

Figure 5 - Map of Recommended Sampling Stations for Quanset Demonstration

d) Water Quality Monitoring Locations: Little Pleasant Bay Demonstration

To establish whether there is an effect on water quality from the additional oysters being grown, ten (10) sampling stations are proposed. As shown in Figure 6, these stations are located within and directly below the grant areas, enabling direct analysis of the water as it flows through the growing areas.

e) Monitoring Shellfish Growth and Survival at Quanset Pond

In addition to water quality sampling, monitoring the numbers of shellfish, as well as growth and survival rates is also recommended. Remote set oysters should be randomly sampled both from floating bags and from trays, and measured every two weeks to establish a growth rate. Survival should be quantified monthly in both floating bags and trays. Before the oysters are bottom planted in the first growing season, population density should be established, and population counts should be made. Observations regarding predation and other stressors should be recorded. The population density should also be measured at the beginning of the second growing season.

The first year report documenting the demonstration projects at the end of the first season should include:

- Population density and overall population counts;
- Number/percent survivors for one year of growth;
- Evaluation of growth rates and survival in trays versus floating bags;
- Size classes by length for one year of growth;
- Area of bottom covered by remote set;
- Review of viability of site for shellfish growth;
- Assessment of operation and maintenance requirements of trays versus floating bags;
- Useful modifications to the site selection criteria for shellfish;
- Recommendations on the type of shellfish grown and whether there should be a mix of species; and
- Assessment of abutter compatibility and use conflicts.

Figure 6 - Map of Recommended Sampling Stations for Little Pleasant Bay

To determine nitrogen uptake from the oyster reef, a measure of the nitrogen content in the shell and soft tissue should be performed for each size class of oyster, as follows:

- Measure dry weights of shellfish tissue and shell separately, using a pooled sample of 10-20 animals;
- Measure the percentage of N in tissue and shell separately, using a pooled sample of 10-20 animals;
- Tabulate wet weight to dry weight correlations using regression analysis;
- Determine nitrogen uptake by total weight of shellfish in each size class:
    - Use correlation between the total wet weight of shellfish (shell and tissue) in each size class and dry weight; and
    - Multiply by percent nitrogen for size class.

This plan is consistent with the Cape Cod Commission’s draft monitoring plan recommendations (Appendix B).

4. Data Collection Needs Summary

a. Data Collection Needs Summary for Year 1 PRB Demonstration

- Baseline groundwater monitoring: one month to install wells and collect samples;
- EVO initial injection test monitoring: four to 6 weeks following initial injection of EVO; and
- Demonstration performance monitoring: once prior to EVO injection, then quarterly for three years.

b. Data Collection Needs Summary for Year 1 FCW Demonstration:

- Water quality analysis in Lonnie's Pond:
  - Continuous data sondes; and
  - Discrete measurements using grab samples/probes.
- Plant community structure on FCW;
- Laboratory analysis of vegetation biomass; and
- Laboratory analysis of biofilms on pucks.

c. Data Collection Needs Summary for Year 1 Shellfish Demonstrations

- Quahog population survey in Pleasant Bay and Town Cove;
- Baseline water quality in terminal pond selected for demonstration;
- Baseline water quality in Quanset Pond;
- Baseline water quality in shellfish private lease area in Pleasant Bay;
- Baseline biodiversity and predators in terminal pond selected for demonstration;
- Baseline biodiversity and predators in Quanset Pond;
- Baseline biodiversity, predators and disease in shellfish private lease area in Pleasant Bay;
- Baseline sediment denitrification rates in selected terminal pond;
- Baseline sediment denitrification rates in Quanset Pond;
- Project viability study monitoring:
  - Shellfish growth and survival;
  - Project logistics during installation, operation and maintenance; and
  - Expense tracking.

d. Data Collection Needs Summary for Year 2 Shellfish Demonstrations

- Water quality monitoring in quahog propagation sites in Pleasant Bay and Town Cove;
- Water quality in terminal pond selected for demonstration;
- Water quality in Quanset Pond;

- Water quality in private shellfish lease area in Pleasant Bay;
- Biodiversity and predators in terminal pond selected for demonstration;
- Biodiversity and predators in Quanset Pond;
- Biodiversity, predators and disease in shellfish private lease area in Pleasant Bay;
- Sediment denitrification rates in selected terminal pond;
- Sediment denitrification rates in Quanset Pond; and
- Project Monitoring for Non Water Quality Factors:
  - Shellfish growth and survival;
  - Project logistics during installation, operation and maintenance; and
  - Expense tracking.

5. Recommended Actions for 2016

The following monitoring activities should proceed during the spring and summer of 2016:

- Baseline groundwater monitoring: one month to install wells and collect samples;
- EVO initial injection test monitoring: four to 6 weeks following initial injection of EVO;
- Baseline water quality monitoring for shellfish demonstrations;
- Disease/predation study for shellfish demonstration; and
- Baseline population study for quahogs,

For PRBs, these initial hydrogeologic and EVO injection studies are needed to finalize the demonstration design. For shellfish project, baseline water quality, quahog populations and predation should be established this season in anticipation of a full-scale demonstration installed next season (Spring/summer 2017). The FCW monitoring program includes monitoring after installation. Since this is not planned to occur in 2016, no monitoring for FWCs is recommended.