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

508.833.6950 tel
508.833.6951 fax

Memorandum

To	George Meservey, Director of Planning & Community Development Michael Domenica, PE, Program Manager
CC	Betsy Shreve, AICP, AECOM Project Director Terry Doss, Biohabitats Pete Muñoz, Biohabitats
Subject	**Town of Orleans, MA** **Water Quality and Wastewater Planning** **Task Number 3.3 – Draft 50% Floating Constructed Wetland NT Demonstration Project Work Plan**
Project Number	60476644
From	Thomas Parece, P.E., AECOM Project Manager
Date	February 18, 2016

1. Introduction

a. Purpose of FCW Demonstration Project

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

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

- Reduce nutrients;
- Realize associated ecological and socioeconomic benefits;
- Evaluate uncertainties associated with the local climate and environmental conditions;
- Assess local water quality and ecological benefits; and,
- Provide a case study to guide future projects.

The pilot project will be built as a temporary structure and will be monitored throughout the life of the project. If necessary, the structure can be removed at any time during the project or after the monitoring period is complete. However, if deemed appropriate, the FCWs could remain in place and continue to provide benefits after the demonstration project is complete.

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

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

b. Purpose of FCW Work Plan

The FCW Work Plan sets forth the preliminary design of the FCW, including the project components, sequencing of subtasks, the equipment, labor and other resources required to construct the FCW, and a preliminary cost estimate. The FCW Work Plan also sets forth a draft monitoring and maintenance plan, along with potential regulatory requirements and funding sources.

The purpose of the FCW work plan will be to provide the Town with the detail needed to determine whether or not to undertake the next steps towards the implementation of a demonstration project.

2. Background

a. Recommended Site Location

A series of meetings, reviews and surveys were held to determine appropriate sites for a potential FCW demonstration project, and then to condense the list to a final list of five potential sites: (1) Lonnie's Pond, (2) Namequoit River, (3) Paw Wah Pond, (4) Pochet Neck and (5) Quanset Pond.

Of these five sites, Lonnie's Pond was found to be the most suitable for purposes of a demonstration project primarily because the site's configuration is the most likely to result in meaningful monitoring results. Specific site characteristics that would aid in monitoring success include the ease of access, the distinctive hydrological inputs and outputs, the overall shallow pond depths, and the potential lack of user conflict.

The four other final sites were found to be suitable for purposes of siting a FCW system; however, their site properties were found to be more difficult to monitor and measure changes in water quality. Specifically, although Quanset Pond and Paw Wah Pond are similar to Lonnie's Pond in many ways, in general these two sites have a relatively smaller surface area available for use for the FCW project and in general are deeper. Namequoit River and Pochet Neck are much more open systems, hydrologically, and would present additional challenges when trying to measure water quality differences due to the placement of the FCW.

b. FCW Attributes

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

FCW meet the following core design principals:

- Utilizing natural, low-tech treatment technologies where possible;
- Minimizing energy use and mechanical system complexity;
- Incorporating educational and interpretive value into the system; and
- Developing systems that are easy to maintain and operate to ensure long-term viability.

The key feature of FCWs is their high surface-area-to-footprint ratio, which enables them to perform functions similar to a natural wetland treatment system. The larger surface area created by the plant roots increases sedimentation, microbial decomposition, nitrification and denitrification, and alters water chemistry.

FCWs remove pollutants from the water column by four main processes: physical, biogeochemical, microbial and plant utilization. Denitrification by FCWs occurs by producing anoxic conditions through the restriction of oxygen diffusion into the water column and is the primary expected mode of nitrogen removal. Also, roots and plant litter act as sorption sites that develop biofilms which increase denitrification rates and thus nitrate removal rates. Plant uptake is only a small source of overall nitrogen removal.

c. Information Gaps to be addressed in Spring/Summer 2016 prior to full scale implementation.

To implement the FCW DP and allow for the most effective siting, the following additional data will need to be collected to supplement the initial site investigation:

- Benthic conditions including sediment characterization;
- Site specific tide gage information;
- Water elevation depths at mean low tide and lowest low tide across the pond; and
- Confirm utility and infrastructure locations in and around the pond.

3. Site Specific Assessment for Preliminary Design

a. Site Specific Conditions of Lonnie's Pond

As previously described, Lonnie's Pond was chosen as the most suitable site for purposes of the FCW demonstration project. The primary reasons that Lonnie's Pond was chosen include its easy access for construction and monitoring/maintenance purposes, the limited hydrological inputs to the pond which allow for more effective monitoring and its relatively shallow depths across the pond. Also, Lonnie's Pond was regarded as likely having limited potential for conflicts given its relatively large surface water area, approximately 14.5 acres, and relatively low number of permitted moorings, which were reported by the Town of Orleans Harbormaster to be 37. In contrast, Arey's Pond, which is approximately 13 acres, has 86 moorings while Paw Wah Pond is approximately 5.5 acres and allows for 26 moorings.

Lonnie's Pond is an intertidal, salt water sub-embayment of the Pleasant Bay Estuary, located off of the upper section of The River. Lonnie's Pond is also part of the Pleasant Bay Estuary Area of Critical Environmental Concern. This sub-embayment receives freshwater discharge, primarily in the form of groundwater discharge or groundwater fed surface water flow, from the surrounding upland areas. The groundwater flow is part of the Pleasant Bay Basin watershed, within the Kescayogansett Pond, Lake and Stream subbasins, and flows from west to east. The surface water flow inputs to Lonnie's Pond include a cranberry bog discharge pipe that drains into the northwest section of the pond and a herring run that links Pilgrim Lake with Lonnie's Pond. These freshwater flows mix with incoming saltwater flows from twice daily tidal inundation that flow through a narrow channel from The River. The site discharges to the Pleasant Bay Estuary during the twice daily outgoing tides.

As a small, semi-enclosed hydrological system, the pond is at risk of eutrophication from high nitrogen loads entering the pond via direct groundwater seepage and surface water inflows. Potential impairments to the water quality of the pond include excess nutrients, low dissolved oxygen levels, high chlorophyll, excess macroalgae, and resultant degraded health of benthic fauna. The 2006 MEP report estimates that existing nitrogen loads are 4.3 kg/day.

The semi-enclosed nature of the system may allow for a more efficient monitoring program due to the confined hydrological inputs and outputs to the pond. One of the goals of the FCW demonstration project will be to show decreased nitrogen rates from water coming into contact with the FCW structures. Capturing these differences in a complex hydrological system with twice daily tidal exchanges will prove challenging. However, a small semi-enclosed pond with discrete inputs and outputs such as Lonnie's Pond will allow monitoring stations to be set upon either side of the FCW unit at the input and output areas to try to capture those differences.

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

Salinity in Lonnie's Pond ranges from 29 to 31 ppt and surface water temperatures generally range from 21 to 24 degrees F (Alliance 2009, The Cadmus Group 2015).

There is a public boat dock on the western edge of the site, which will allow for easy access via motorized boats and working kayaks for installation of the FCW units and for regular monitoring and maintenance activities. The public access ramp is noted as accommodating up to six parking spaces.

The land use around Lonnie's Pond is residential, and private ownership of the land extends to the low tide water line. The area is not densely populated, and areas along the tidal channel (Kent's Point) that link the pond with the bay are protected by the Orleans Conservation Trust.

The land below the waters, where the FCWs would be anchored, is held in Public Trust by the Town of Orleans. Per the public trust doctrine, the public has the right to certain uses (fish, fowling, and navigation) between the mean low and mean high tide lines. Based on consultation with the Orleans Town Assessor, the land below the mean low tide line is likely owned by the Town of Orleans, although this will be confirmed through legal review.

b. Describe any assumptions made about site due to information gaps requiring confirmation

Due to winter conditions, certain site features could not be ascertained before the development of the preliminary concept, as described in the previous section. For purposes of this preliminary design, therefore, the following assumptions were made:

- The FCW could be anchored within Lonnie's Pond. This assumption is based on the number of moorings that already exist within the pond;
- The typical daily tides within the pond range from five to six feet. This is based on the MEP reports for Pleasant Bay and its subembayments;
- There is sufficient area to site the FCWs with a two to three foot water depth at mean low tide near the discharge areas for the stormwater pipe and the herring run;
- The preliminary siting locations for the FCWs in Lonnie's Pond will not affect or in any way disrupt existing utilities and infrastructure in and around Lonnie's Pond; and
- There is enough water surface area within Lonnie's Pond to site FCWs that will utilize approximately ten percent of the surface water area within the pond so that there will be no disruption to the community and other users of the pond.

4. Preliminary Design

a. Site Configuration

To most effectively capture the nitrogen-laden surface water entering into 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.

A preliminary design, illustrating these concepts, is provided in Appendix A.

b. Project Components

- **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.

c. Sequencing of Subtasks

To achieve a full growing season and the most efficient use of the FCWs, the FCW units should be installed in early May and planted at that time. The FCW units can be installed and planted at any time of the year, but full growth of the plants and their root systems can best be achieved by planting in the spring.

Alignment of the islands by the inputs will be perpendicular to the shoreline, and will be based on a two-three foot depth at mean low tide to achieve the proper vertical depth above the benthic environment.

To deploy the islands, the following tasks will be undertaken:

- Manufacturing of the module frames off site;

- Delivery of the module frames and other materials to the project site;

- Unit assembly of the modules by attaching the coir to the frames;

- Planting of the modules;
- Connecting nine modules into clusters;
- Placement of anchors and mooring lines;
- Towing units to anchors and mooring;
- Cabling and Connecting.

d. Labor resources needed to install the FCW DP

Construction activities will be managed to limit disturbance to the residential community, lake access and recreational activities. All HDPE welding will be done in factory. Onsite activities will include receiving manufactured wetland modules, placing coir in module, planting, bolting together, placement and anchoring. A fork lift will be used to remove material off of delivery trucks. A boat will assist with island placement at the anchor/moor locations.

The construction crew will consist of 6 to 10 people for approximately 3 weeks.

e. Issues considered during preliminary design:

- In-situ versus laboratory monitoring of nitrogen removal;
- Lower DO in area around FCW;
- Excessive organic loadings from detritus;
- Concentrations of metals or other contaminants;
- Attraction of waterfowl that could add to the loadings;
- Invasion by weeds from islands;
- Long-term buoyancy; and
- Overall durability.

5. Monitoring and Maintenance

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.

a. 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 bathymetric surveys and tidal amplitude from continuous datalogging levelloggers.

b. Monitoring for 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.

c. 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 reference estuarine FCW in the Baltimore area for comparison with referenced data from local natural marshes.

d. 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;

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

6. Project Cost Estimate

A cost estimate for the FCWs was estimated and is provided in Appendix B. The cost estimate is based on the conceptual design, and will be refined after additional engineering analyses are conducted. The cost estimate includes the following elements:

- Mobilization and Demobilization;
- Fabrication (base material, anchoring, cabling);
- Plant and Planting Medium;
- Installation;
- Maintenance;
- Monitoring – Lab and In-Situ;
- Contingency; and
- Town Administration and Engineering.

7. Regulatory Considerations

The FCW Demonstration Project would be located in a resource area subject to jurisdiction by MassDEP under the Massachusetts Wetlands Protection Act (WPA) regulations (310 CMR 10.00), Chapter 91 regulations, (310 CMR 9.00), and 401 Water Quality Certification regulations (310 CMR 4.00), while the US Army Corps of Engineers has jurisdiction over the pond under the federal Clean Water Act. In addition, the Town of Orleans Conservation Commission has jurisdiction over Lonnie's Pond under both the Orleans Wetland By-law and the MA WPA regulations. Lonnie's pond is located in an Area of Critical Environmental Concern (ACEC), which triggers the need for MEPA review. Based on available on-line mapping tools available from the MA Natural Heritage and Endangered Species Program (NHESP), the pond appears to be located just outside of an area of Estimated Habitat of Rare Wildlife that includes most of Pleasant Bay.

Installation of the FCW Demonstration Project would require either a Request for Determination of Applicability (RDA) or a Notice of Intent filing with the Orleans Conservation Commission. It is recommended that consultation with the Commission occur to determine the appropriate application mechanism. The Chapter 91 regulations allow the placement of temporary moorings, floats and rafts may be allowed through an annual permit issued by the Orleans harbormaster; it is anticipated that this

authorization process could be allow for the installation of the temporary FCW islands, although further consultation with the harbormaster is required in regard to this review and approval process. The installation of temporary moorings are allowed as a non-reporting activity by both the USACE and MassDEP under the General Permits for Massachusetts; therefore applications under Sections 404 and 401 of the Clean Water Act are not anticipated to be necessary. A MEPA filing for the update to Orleans Wastewater Management Plan is envisioned, and should include the FCW Demonstration Project. Consultation with MA NHESP is also recommended to confirm that the FCW Demonstration Project would be outside of MA NHESP Priority Habitat Areas.

8. Potential Funding Sources

Deliverables developed under Task 5 include an evaluation of general funding mechanisms for the overall wastewater management project, including options such as SRF funding, Mass DEP 604b/319 grants, and USDA rural development grants. In addition to the funding sources discussed as part of Task 5, potential funding sources available specifically for constructed wetlands were researched. Availability of these funding sources would be dependent on a successful application process, and also on application submittal deadlines as compared to the FCW DP schedule. Deadlines for many grants have passed or are imminent for the current calendar year, although submitting an application for a 2017 project might be feasible. The potential funding sources and websites with additional information on each funding opportunity are listed in the following table:

Potential Funding Sources for Floating Constructed Wetland Demonstration Project

Grant Title	Website
US EPA Wetlands Program Development Grants	https://ofmpub.epa.gov/apex/watershedfunding/f?p=109:2:::NO::P2_X_PROG_NUM,P2_X_YEAR:65,2015
North American Wetlands Conservation Fund	https://www.cfda.gov/index?s=program&mode=form&tab=core&id=97dc7d8a3d12b63a01dec93e3a73c1c9
U.S. Fish and Wildlife Service, Wildlife and Sport Fish Restoration: National Coastal Wetlands Conservation Grant Program	http://www.fws.gov/coastal/CoastalGrants/index.html.
5 Star Wetland and Urban Waters Restoration Grants	http://www.nfwf.org/fivestar/Pages/home.aspx
MA CZM Coastal Pollutant Remediation (CPR) Grant Program	http://www.mass.gov/eea/agencies/czm/program-areas/coastal-water-quality/cpr/.
North American Wetlands Conservation Act Grants	http://www.fws.gov/birds/grants/north-american-wetland-conservation-act.php
Massachusetts Environmental Trust (MET) General Grants	http://www.mass.gov/eea/grants-and-tech-assistance/grants-and-loans/mass-enviro-trust/met-grants.html.

9. Projected Full Scale Approach

If FCW were implemented as part of the full scale Non-Traditional project, it is anticipated that there would be additional FCWs installed at some or all of the other sites identified in Pleasant Bay, including Namequoit River, Paw Wah Pond, Pochet Neck and Quanset Pond. No potential sites have been identified for either the Town Brook or Rock Harbor watersheds, so it is not anticipated that full-scale implementation would include FCWs in these watersheds.

As indicated above, a number of regulatory approvals are required for the FCW DP and it is anticipated that similar approvals would be required for full-scale implementation. In addition, it is anticipated that MassDEP would issue a watershed permit approving the full-scale implementation. Details of the watershed permit and any conditions to be included therein are unknown at this time; however, full-scale implementation would be required to in accordance with the conditions of the watershed permit. Full scale implementation is also contingent upon monitoring results that demonstrate favorable nitrogen removal.

10. Summary and Next Steps

Technologies that could be co-located with the floating wetlands:

- Some type of solar-powered aeration located on the wetlands to boost DO levels in the root zones;
- Additional media at the floating wetlands (geotextile perhaps, cut in strips – kelp style) to maximize surface area for attached growth; and,
- Some additional DO boosting elsewhere in pond – either combining with more active microbial zones in edge wetlands with compressor powered small bubble aeration in gravel beds, or floating windmills.

These alternative adaptations proposed for the FCW utilize the lake restorer developed by John Todd (Todd 1996) and further demonstrated (Yaron et al. 2000, Kangas 2004) as a modification of the “living machine” concept. The existing FCW design proposed would actively pump and recirculate water through the system, optimizing each step in the process with treatment occurring similar to that of a treatment wetland. Specialized nitrification and denitrification conditions and mechanisms in the treatment train may provide higher nitrogen removal performance in creating N2 gas dissipating from the lagoon system.

11. References

Kangas, P. C. 2004. *Ecological Engineering: Principles and Practice*. Lewis Publisher, CRC Press. Pp 193-195.

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

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

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

Todd, J. 1998. Why lake restorer living machines work. Annals of Earth. 14(2):12-14.

Yaron, P., M. Walsh, C. Sazama, R. Bozek, C. Burdette, A. Farrand, C. King, J. Cignola, and P. Kangas. 2000. Design and construction of a floating living machine. Pp. 92-101. In: *Proceedings of the 27th Annual Conference on Ecosystems Restoration and Creation*. P.J. Cannizzaro (ed.). Hillsborough Community College, Plant City, FL.

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

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

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

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

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

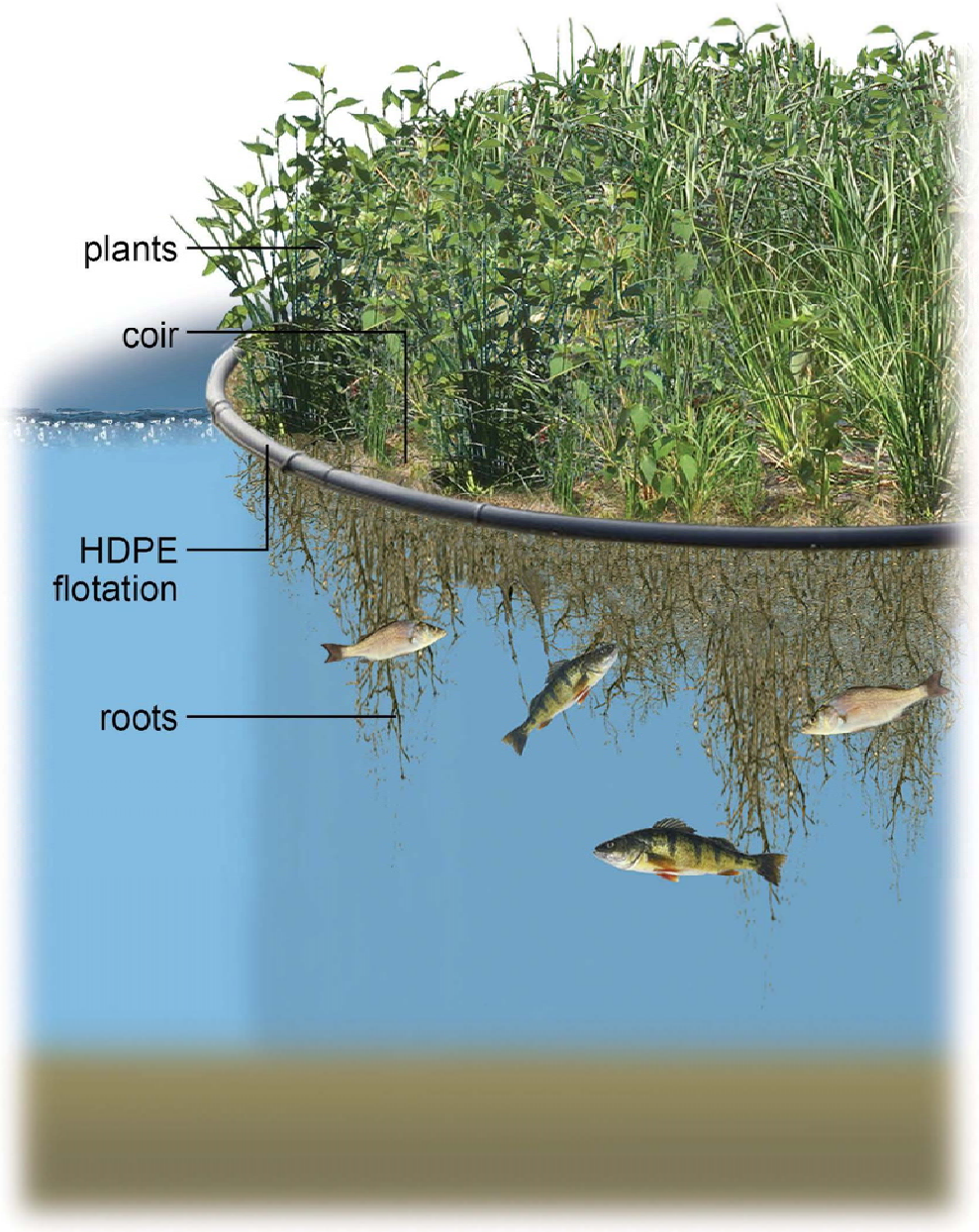
Winston, R. J., Hunt, W. F., & Kennedy, S. G. (2012). Evaluation of floating wetland islands as a retrofit to existing stormwater detention basins. In *World Environmental and Water Resources Congress 2012: Crossing Boundaries, Proceedings of the 2012 Congress.* (pp. 274-284). 10.1061/9780784412312.030

This Page Intentionally Left Blank

Appendix A

Conceptual Illustration

Preliminary Design

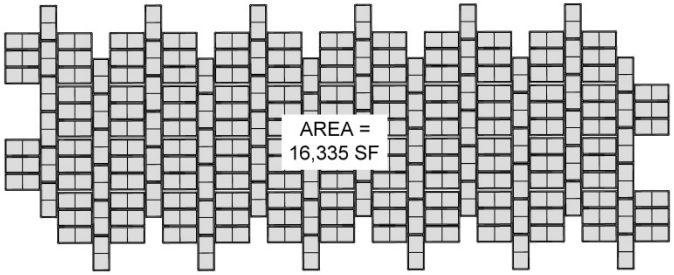


Floating Constructed Wetland Conceptual Illustration

AECOM

FLOATING CONSTRUCTED WETLAND SITE PLAN

HORIZONTAL SCALE
0 100 200



FLOATING CONSTRUCTED WETLAND (24 MODULE CLUSTERS)

HORIZONTAL SCALE
0 20 40

CLIENT

Town of Orleans, MA
Water Quality and Wastewater Planning
Task Number 3.3
Floating Constructed Wetland NT Demonstration Project

DATE:	ISSUES / REVISIONS
01/26/16	FLOATING CONSTRUCTED WETLAND CONCEPT (NOT FOR CONSTRUCTION)

Biohabitats
HUDSON RIVER BIOREGION
402 West 40th Street
New York, NY 10018 / ph: 800.220.0919
www.biohabitats.com
Restore the Earth & Inspire Ecological Stewardship

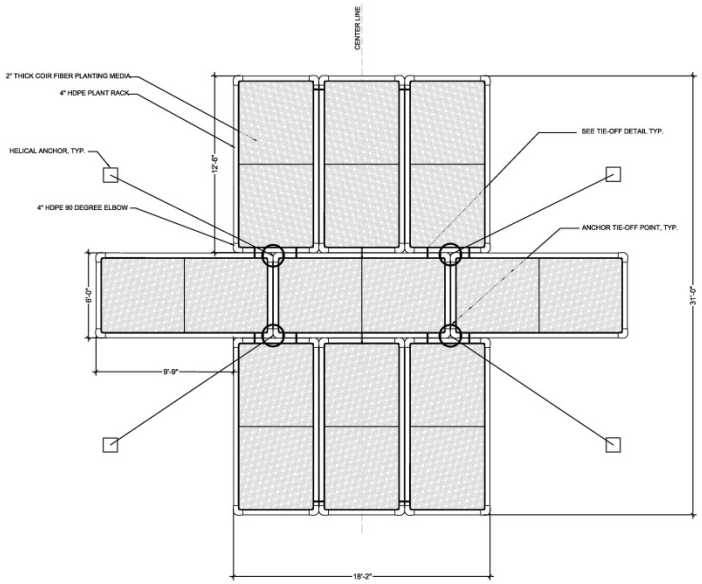
FLOATING CONSTRUCTED WETLAND NT DEMONSTRATION PROJECT

TITLE:
PROPOSED PLAN

PROJECT NO.: 15404.01
SCALE: AS LISTED
SEAL:
BY: PM/MS
CHECK: TD/PM
DWG. NO.:
01 OF 02

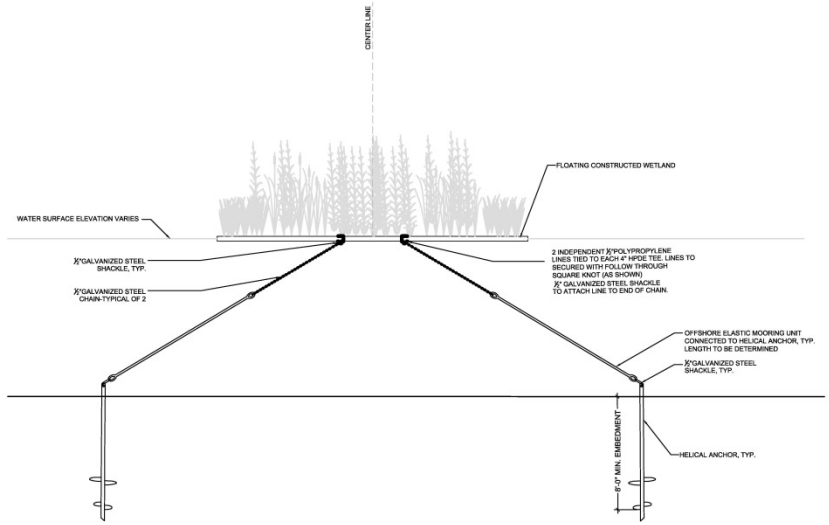
1/26/2016

Reuse of Documents: This document, and the ideas and designs incorporated herein, as an instrument of Professional Service, is the property of Biohabitats, Inc. and is not to be used in whole or in part, for any other project without the written authorization of Biohabitats, Inc.



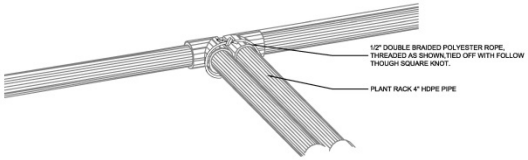
1 FLOATING CONSTRUCTED WETLAND MODULE CLUSTER

SCALE: 1/4" = 1'-0"



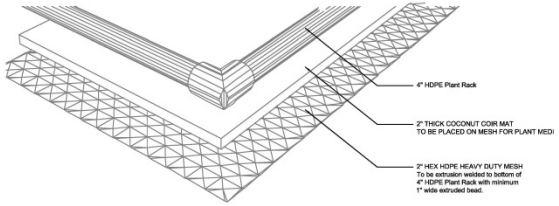
2 FLOATING CONSTRUCTED WETLAND ELEVATION AND ANCHORING DETAIL

SCALE: 1/4" = 1'-0"



3 TIE OFF DETAIL

SCALE: NOT TO SCALE



4 PLANT RACK FABRICATION

SCALE: NOT TO SCALE

CLIENT

Town of Orleans, MA
Water Quality and Wastewater Planning
Task Number 3.3
Floating Constructed Wetland NT Demonstration Project

DATE:	ISSUES / REVISIONS
01/26/16	FLOATING CONSTRUCTED WETLAND CONCEPT (NOT FOR CONSTRUCTION)

Biohabitats
HUDSON RIVER BIOREGION
402 West 40th Street
New York, NY 10018 / ph: 800.220.0919
www.biohabitats.com
Restore the Earth & Inspire Ecological Stewardship

FLOATING CONSTRUCTED WETLAND NT DEMONSTRATION PROJECT

TITLE: DETAILS

PROJECT NO.: 15404.01 | SCALE: NTS
SEAL: | BY: PM/MS | CHECK: TD/PM
DWG. NO.: 02 OF 02

1/26/2016

Reuse of Documents: This document, and the ideas and designs incorporated herein, as an instrument of Professional Service, is the property of Biohabitats, Inc. and is not to be used in whole or in part, for any other project without the written authorization of Biohabitats, Inc.

Appendix B

Estimated Project Costs

Annual Operation and Maintenance Costs

Replacement Costs

Annual Monitoring Costs