3 Non-Traditional Nitrogen and Wastewater Management Technologies and Evaluations

3.1 Introduction

During the six-year period of detailed evaluations, there evolved an increasing focus on non-traditional nitrogen and wastewater management technologies as a way to implement more economically viable and environmentally sustainable wastewater and nitrogen management solutions. Many of these technologies had not been used in the United States as part of a municipal-scale wastewater management plan and their feasibility was uncertain. After much Town decision-making led by the CWMP Review Committee, Article 17 (attached in Appendix 1-1) was presented and adopted at the 2011 Annual Town Meeting. Since then, the Town's WQMC has implemented this directive by initiating a group of Demonstration projects to investigate the feasibility of the following non-traditional nitrogen management technologies and processes:

- Shellfish Aquaculture Demonstration Project to harvest/mitigate excessive nitrogen in the estuaries.
- Inlet Widening of Bournes Pond.
- Eco-Toilet Demonstration Project which investigates the use of composting and urine-diverting toilets.
- Permeable Reactive Barriers (PRBs).
- Stormwater management initially to be evaluated for the Little Pond watershed.

Two other initiatives (not demonstration projects) have commenced detailed evaluations and are expected to provide additional nutrient management and include:

- Development and recent Town passage of a Comprehensive Nitrogen Control Bylaw (for fertilizer).
- Information-gathering on the feasibility and performance of individual property and clustered nitrogen removal (denitrifying) septic systems.

The eco-toilet, PRB, and on-site denitrifying septic system technologies had previously been screened from further evaluations in the 2007 Alternatives Screening Analysis Report and the ENF Document. They were formally added back into the detailed evaluations through the filing of the 2012 Draft Report that had a Notice of Project Change to evaluate these—and other—items.

Two other non-traditional technologies (management concepts) were evaluated but were not identified in Article 17 for demonstration projects and include:

- Ocean Outfall Discharge for Treated Water.
- Potential Watershed Modifications for Increased Nitrogen Attenuation.

The ocean outfall concept had been previously screened from further evaluation in the Alternatives Screening Analysis Report and the ENF Document. It was added back into the detailed evaluations through the filing of the 2012 Draft Report and Notice of Project Change.

The demonstration projects and other non-traditional nitrogen and management initiatives are proceeding. Further efforts will continue independent of this CWMP Project. Once they are determined to be feasible and cost-effective, they will be submitted as part of a Notice of Project Change for review by MEPA, and integrated into the CWMP Project for implementation. These detailed evaluations are summarized below with progress summaries and expected next steps.

The Town also identified that a key component of its successful implementation of any of these approaches (non-traditional or traditional) would be to significantly increase water conservation by retrofitting all structures within the Town (public and private) with low-flow devices.

3.2 Shellfish Aquaculture Demonstration Project to Harvest/Mitigate Excessive Nitrogen in the Estuaries

Shellfish aquaculture is an established industry on Cape Cod. It employs many producers, and yields a valuable end product. Applying shellfish aquaculture to nitrogen management is a non-traditional approach for improving water quality in estuaries. Oysters have been selected for the demonstration project because they remove significant amounts of nitrogen due to their relatively fast growth over other endemic shellfish. In addition, culture techniques are well known and oysters have a high market value.

Oysters are highly efficient filter feeders, consuming the plankton which grows on dissolved nitrogen and other nutrients in the water. The plankton proliferates excessively because of the high nutrient inflows to the pond. These algae then die and decompose, releasing more nutrients such as hydrogen sulfide that causes odors and can lead—in some instances—to fish kills. In addition, the algal blooms increase the biological oxygen demand in the estuaries that can approach nearly anoxic conditions. This also stresses the fish and other aerobic organisms living in the water. By feeding, oysters manage the concentration of plankton that continues to regenerate and grow on dissolved nutrients. In this way, oysters improve water quality. It has also been shown that shellfish waste products may augment denitrification of bottom sediments, thereby releasing nitrogen in the form of nitrogen gas to the atmosphere, 78-percent of which is already nitrogen gas.

Working through the WQMC and the Department of Marine and Environmental Services, the Town has achieved a number of milestones and has launched the full-scale implementation of the demonstration project. The goal is to establish and quantify the causal relationship between shellfish cultivation and improved water quality. Accomplishments to date include:

- Viability Test Completed (summer 2012).
- Conservation Commission Notice of Intent (NOI) hearing, and Order of Conditions issued on May 10, 2013.
- Department of Marine Fisheries permit approval.
- Oyster Aquaculture Demonstration Program (Demonstration) Plan developed.
- Staff hired, and equipment and shellfish purchased.
- Seed installed in Town upweller.
- Floating nursery and grow-out bags established in Little Pond.

- Installation of first batch of oysters into Little Pond for first year of demonstration project expected by June 30, 2013 with second batch for the first year by July 31, 2013.
- Monitoring Plan formalized with MassDEP and Falmouth Conservation Commission.

By the end of the first year, the following will have been achieved:

- First batch relayed to other Falmouth estuaries for six-month depuration, further growth, and harvest by recreational and commercial shellfishers.
- Second batch prepared for and moved to overwintering site in Little Pond.

3.2.1 Shellfish Aquaculture Demonstration Project Description

Implementation of the Oyster Aquaculture Demonstration Project began in the spring of 2013. The plan is to grow two batches of 1.25 million juvenile oysters each, for a total of 2.5 million. 1.25 million oysters were purchased and installed in the Town upweller on May 28. This batch will be moved to Little Pond in late June. Immediately after that, the second batch will be installed in the upweller and moved to Little Pond at the end of July. These will be grown in approximately 2,000 floating bags. The June batch will be transferred to other estuaries in Falmouth for clean-out and further growth at the end of summer. The July batch will be overwintered by submerging it in the pond for further growth in 2014. Oyster growing in 2014 and 2015 will also use the late batches of oysters overwintered from the previous year, supplemented by a single batch of early seed put in the pond at the beginning of the growing season. Thereby, two year classes will be cultured simultaneously. The floating bags will be of the same type that was used for the oyster survival test in Little and Green Ponds during the summer of 2012.

A water quality monitoring program has been established in close coordination with MassDEP and Falmouth Conservation Commission. MassDEP has indicated that three years of water quality data is needed to form the basis of a TMDL-credit for nitrogen removal that is attributable to oyster aquaculture. Appendix 3-1 contains the Scope of Services for this Monitoring Plan as well as other documents referenced in this section. In general, water samples will be taken twice monthly from June through October. This monitoring protocol includes nutrients as well as other water quality parameters[1] and surveys of benthic organisms. This suite of water quality factors is based on those analyzed as part of the Little Pond MEP Report. In addition, during July and August, data will be collected in 1-hour intervals using two continuous monitoring buoys. Sampling parameters include dissolved oxygen, salinity, temperature, pH and turbidity. Discharge from a storm drain near the project site will also be monitored. The purpose of this monitoring plan is to develop an estimate of the amount of nitrogen that can be removed from the water through plankton consumption and incorporation into oyster growth.

The demonstration project plans to have public information sessions from time-to-time to seek input, particularly from residents in the Little Pond area, during the set-up and production stages.

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[1] Total nitrogen (nitrate, nitrite, ammonia, dissolved organic nitrogen, particulate organic nitrogen), temperature, pH, chlorophyll-a, pheophytin-a, orthophosphate, salinity, dissolved oxygen, transparency (Secchi depth), benthic condition (periodical), other parameters as specified in the Quality Assurance Assessment Plan, as well as shellfish weight (periodic).

3.2.2 Background Research and Analysis

In the summer of 2012, a Shellfish Viability Test was conducted by the Town to demonstrate initial feasibility. A complete write-up of this milestone is in Technical Memorandum OA-TM-2. This Test included the following test methods and results:

- Three oyster bags in Little Pond.
- Three oyster bags in Green Pond.
- Use of oysters as the shellfish for the viability test.
- Seed and gear was donated to the Town by a local oyster grower.
- Work was under the direct oversight of the Town through the Shellfish Constable.
- Viability Test was done utilizing volunteers—so there is no initial cost.
- Examine/check oysters roughly weekly and measure the survival and growth rates at the end.
- Oysters from Little Pond grown as part of the viability testing were destroyed—landfilled or equivalent—as they were not for consumption or relay.
- Oysters were tested for health/disease.

While the expectation was that there will be roughly a 50-percent survival rate, the results of the viability study show much lower mortality rates (only 1 out of 1,247 individuals). This is likely due to a combination of factors: good husbandry, resilient genes, lack of predation, and low stocking densities. Subsequent disease testing of a sample of the Little Pond oysters revealed no Multinucleated Sphere Unknown (MSX) or Dermo. Part of the finding of the demonstration will be an assessment of the mortality of larger-scale oyster cultivation. Based on the success of this test, the Town hired Woods Hole Group to assist with the planning for this project. Their research and analysis can be found in Technical Memoranda 1 through 4,. These reports include:

- Stock Assessment Report.
- Technical Memorandum No. 1 (OA-TM-1): Little Pond Viability Test Review.
- Technical Memorandum No. 2 (OA-TM-2): Program Planning Estimates and Discussion of Findings.
- Technical Memorandum No. 3 (OA-TM-3): Management Plan: Project Specifications and Cost Estimate.
- Technical Memorandum No. 4 (OA-TM-4): Implementation Plan.
- Educational Brochure.

The Stock Assessment Report and Little Pond Viability Test Review (OA-TM-1) confirmed that oysters are likely to survive and grow in Little Pond.

Selecting oysters from the range of options available was based on the information provided in OA-TM-2. The following species of shellfish were considered:

- Oysters (Crassostrea virginica).

- Quahog Clams (Mercenaria mercenaria).
- Soft Shell Clams (Mya arenaria).
- Mussels (Mytilus edulis).
- Bay Scallops (Argopecten irradians).
- Ribbed Mussels (Geukensia demissa).

In addition to the nitrogen assimilation capacity, of particular importance to species selection, was the likelihood of grow-out success. Once oysters were chosen, the data on nitrogen removal and cost were carefully considered by the WQMC.

Technical Memoranda OA-TM-2 and OA-TM-3 provide information on several key variables that significantly impact the cost and nitrogen removal of shellfish, including:

- Seed starting size (2mm, 6mm, 12mm, 18mm).
- Initial number of seed (0.5M, 1.0M, 1.5M, 2.0M).
- Gear choice (floating bags or submerged cages).
- Nitrogen-removal capacity as percent of total nitrogen load.

A critical demonstration criterion is to be able to measure a change in nitrogen in the water after oyster installation and growth. The total nitrogen load for Little Pond came from the Little Pond Massachusetts Estuaries Project (MEP) Final Report (2006). In addition, a model calculation of the likely daily mass of nitrogen that would be present in the water column was developed. These values and information on the standard deviation of the data in the MEP Report for Little Pond were compared to validate that the quantity and starting size of oysters could remove a mass of nitrogen that is likely to be measurable through each growing season over the 3-year project duration. In particular, the percentage change of nitrogen over seasonal (May-October) load when the MEP studies indicated the nitrogen Sentinel Threshold would need to be achieved and daily flux were used as the basis for determining how many oysters to grow in order to be able to measure a change in nitrogen concentration. For the colder months of the year, the MEP reports indicated that dissolved nutrients in the water would be of little consequence to the health of the ecosystem since there is relatively low or negligible biological activity in the estuaries during that mostly dormant period. Tables 1, 8, 9, 12, and 13 in OA-TM-3 present the values for percent nitrogen removal for the warmer months of the year. Scenarios for intermediate seed start-size were also evaluated. The specifications and a cost estimate for the demonstration for three years included seed, gear, and labor costs organized by varying quantities of seed of different starting size. Tables 2-7 and 2-11, found in OA-TM-3 present this cost information.

The WQMC identified several issues that needed to be balanced in the final design of the demonstration, evaluating a number of different implementation scenarios to fit within the following constraints:

- Economic/budget constraints.
- Area/aesthetic constraints and competing uses of Little Pond for paddling and passive enjoyment.
- Scientific constraints—the need for measurable results over statistical variations in background nitrogen.

- Permitting requirements and compliance.

The final design came through an iterative process of discussion and analysis. Input from a broad range of stakeholder groups was also carefully considered. These groups include Division of Marine Fisheries (DMF), Department of Environmental Protection (DEP), Falmouth Department of Natural Resources (now the Department of Marine and Environment), Falmouth Conservation Commission, local community members and abutters, local shellfish growers and commercial harvesters, the town of Mashpee Shellfish Constable, and several individuals who have either interest in or experience with shellfish cultivation and nitrogen bioextraction methods. While the plan was developed with the intent that the demonstration will be managed by the town, the advantages and disadvantages of a town-sponsored versus private aquaculture grant was also assessed.

Shellfish aquaculture was not considered in the 2009 Alternatives Screening Analysis Report. It is now a key demonstration project in this CWMP. The Monitoring Plan for this Oyster Aquaculture Demonstration Project ensures careful tracking of costs and water quality improvements. If it proves to be a successful nitrogen management method, the CWMP will be modified through Adaptive Management to incorporate shellfish aquaculture more broadly in the Planning Area.

The Woods Hole Group (WHG) calculated that the oyster demonstration project's two-acre culture area, which is approximately 4.4-percent of the total Little Pond area, would assimilate 26-percent of the seasonal nitrogen load (1,250 kg) to the estuary—spring to fall. This value is based on a desktop estimate of published literature for oyster growth and nitrogen-content on Cape Cod. This value assumes that 1.25 oysters of approximately 20-mm (~.75-inch) are over-wintered and begin growing in Little Pond in May of the subsequent spring. Growth to almost 70-mm (almost 3-inches) within this growing season is further assumed. In addition, 1.25 million seed are installed in the spring and reach a size of 20-mm. These WHG calculations are being evaluated under the demonstration project. Indicative results should be available by the end of 2015.

Potentially, 4- to 5-acres of oyster aquaculture can mitigate the seasonal nitrogen load in Little Pond.

Funding for the Shellfish Aquaculture Demonstration Project came from an allocation of $200,000 in Article 17 of the Spring 2011 Town Meeting. This amount was sufficient to conduct the viability testing, purchase the equipment and seed for the first two years, and contract for staff support of the project for two years. The cost of the monitoring for the first year is also funded out of Article 17. New funding or re-allocation of existing funds will be needed for monitoring for two years and seed for the third year of the demonstration project.

3.3 Inlet Widening of Bournes Pond with Considerations for Little Pond

Inlet Widening had been evaluated for Bournes Pond and Little Pond before the passage of Article 17. This analysis indicated that widening these two inlets could provide an immediate and cost-effective improvement in water quality, and reduce the amount of sewering required for traditional wastewater nitrogen management in this watershed. These evaluations are summarized in Appendix 3-2. In addition, a Technical Memorandum (dated March 2008) with more detailed evaluations is attached in Appendix 3-3.

Concurrently, the CCWPC (a Barnstable County organization) had been working to streamline the permitting process for non-traditional wastewater and nitrogen management concepts, with a focus on inlet widening projects. Working with the Town of Falmouth, the CCWPC hired a consultant to prepare and file an Environmental Notification Form and Waiver for the Bournes Pond Inlet Opening in a project called the Bournes Pond Restoration and Improvement Project. The project proposed augmentation of the existing 50-foot bridge over the inlet with an additional 50-foot bridge. Little quantitative information was provided on the benefits and cost of such a project. The regulatory community raised many questions about the proposed project and the ENF was withdrawn.

After the passage of Article 17, the WQMC revisited this option and considered which inlet opening to study further. Bournes Pond was chosen based on the significant gains in tidal flushing and nitrogen removal that seemed to be likely, as well as public support from residents in the Bournes Pond area. Moreover, neighbors in the Little Pond area opposed widening of the Little Pond inlet.

In late 2012, the Town's WQMC initiated the Bournes Pond Inlet Opening Demonstration Project to evaluate this option quantitatively and to obtain greater detail on the implications of such a project. A consultant team (GHD, Applied Coastal Research and Engineering, and BETA Group) was hired to determine optimal inlet opening size, alternative bridge types to maintain the opening, capital and O&M costs of the revised opening, nitrogen management benefits, the effective nitrogen removal that would be provided by the new inlet opening, and potential cost savings of the inlet opening as compared to removing the same amount of nitrogen through conventional wastewater nitrogen management methods. The evaluations and findings are summarized in detail in Appendix 3-4 and briefly listed below:

- The optimal opening size is estimated to be approximately 90-feet as determined by hydrodynamic modeling procedures of the accepted MEP water quality model.
- Four alternative openings and bridge conceptual designs were evaluated to replace the existing 50-foot span bridge and opening, and to extend an additional 40-feet to the east. From the evaluation, a two-span bridge was selected as the most practical and cost-effective at a total capital cost of $5,520,000.
- The accepted MEP water quality model estimated the effective nitrogen removal of the new inlet to be 1,995 kg of nitrogen per year.
- The cost to remove this same nitrogen load through conventional wastewater nitrogen removal (sewering and advanced treatment) was estimated to be from $12,830,000 to $19,130,000 depending on the assumptions used. This indicated a significant saving compared to the $5,520,000 cost of the new bridge and opening. The new bridge and opening would be 43- to 29-percent of conventional wastewater nitrogen mitigation.

Based on these findings, the WQMC and Town have decided to proceed with the following next steps:

- Advance this demonstration project independently of the CWMP Project.
- Continue with permitting and design evaluations, estimated to cost $700,000: (Town Meeting appropriated $300,000 in spring of 2013 and a balance of $400,000 remains in Article 17 funding from 2011 from unspent engineering and inlet widening allocations).
- Submit a Notice of Project Change for this project to have it reviewed by MEPA.
- Proceed with the many permits (local, regional, Commonwealth, and Federal) that would be needed once MEPA approval is obtained.
- Evaluate the effects/benefits of inlet opening through monitoring and implementation.

The estimated capital cost to widen Bournes Pond Inlet is $5,520,000. The Town plans to include this project in its SRF Project Evaluation Form submittal in August 2013, and to include the construction cost in the bond issue to be authorized by Town Meeting in Spring 2014.

3.4 Eco-Toilet Demonstration Project: Composting and Urine-Diverting Toilets

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

There are significant environmental advantages to such a system including:

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

The implementation strategy for eco-toilets involves installations in individual homes, as well as commercial buildings. The 2007 Alternatives Screening Analysis Report (attached in Appendix 2-6) includes a preliminary review of these technologies in Chapter 7. These technologies were eliminated (screened) from further detailed evaluation due to the uncertainty of their performance and acceptability. Additional information on the efficacy and suitability of eco-toilets has become available, warranting their inclusion in the CWMP process. The Notice of Project Change in Chapter 9 of the Draft Report re-introduced eco-toilets to this CWMP Project.

To deploy eco-toilets as a nitrogen-reduction solution, the actual nitrogen removal rates must be determined by sampling. Nitrogen derived from households comes from both human excrement and urine, as well as from showers, sinks, dishwashers, and laundry water. To assess the use of eco-toilets as a non-traditional wastewater management strategy, Falmouth has launched the Eco-Toilet Incentive Program. A key objective of this demonstration is to measure the actual amount of nitrogen that remains in a household waste stream both before and after urine and feces have been removed. There are also a number of questions regarding the cost and feasibility of installing eco-toilet system in existing structures (retrofits), long-term systems operation and maintenance, and overall public acceptance of eco-toilets. Before eco-toilets can become a long-term nitrogen mitigation strategy, these questions must be answered.

This demonstration should assist the town to systematically develop answers to these questions, so that costs and nonmonetary factors can be compared with other traditional and non-traditional methods. The

WQMC, working through its Eco-toilet Subcommittee developed a Memorandum of Agreement with the Barnstable County Department of Health and Environment (BCDHE) to perform sampling and monitoring (see Appendix 3-5) and hired Science Wares, Inc. to design, implement, and manage the demonstration. Details and milestones of the Eco-Toilet Demonstration Program are described in the following sections.

3.4.1 Eco-Toilet Incentive Program Description, Goals, and Objectives

Falmouth's Eco-Toilet Incentive Program will establish how much nitrogen eco-toilets remove from the human waste stream, in order to determine how useful these fixtures will be in TMDL-compliance. A key, long-term objective of the demonstration is to work closely with regulatory agencies to determine the nitrogen removal credit of eco-toilets. MassDEP has provisionally suggested that a total of 62 installations will need to be tested in order to quantify eco-toilets' nitrogen removal credits for regulatory purposes. Based on the results of this first group of installations, further refinement of this number may be possible. Further, these installations will document the technical details of these fixtures, both in terms of installation as well as operation and maintenance. This demonstration will also verify the installation costs and user-experience with eco-toilets. The cost and practicality of retrofitting existing structures with eco-toilets is critical to an evaluation of whether these toilets are a viable alternative to more traditional wastewater management techniques. This demonstration is endorsed by the Cape Cod Commission, and the results of this research will be used to quantify the effectiveness of these toilets in their planning tool entitled "Regional Wastewater Planning Matrix".

Numerous installations of eco-toilets in Europe/Scandinavia and Australia have been documented. Falmouth's demonstration may be unique in that it will include specific measurements and analysis of nitrogen-removal. In addition, participation is completely voluntary. In many international programs, the end-user was not the person responsible for deciding to install an eco-toilet. Finally, the bulk of Falmouth's installations are as retrofits to existing buildings. This allows the Town to assess the particular issues involved with installing eco-toilet in a preexisting stock of homes and businesses.

This demonstration differs from most others in that it includes many different types of eco-toilets from many manufacturers. Most other pilot and demonstration programs test either composting or urine-diverting toilets but not both, and often use only toilets from a single manufacturer. This demonstration was designed to determine the nitrogen removal characteristics of a diverse range of eco-toilets, and to enable the installation of different toilets to fit different retrofit situations. As a result, at the end of the testing period, the Town will have documentation on a wide spectrum of circumstances and challenges encountered when installing and using eco-toilets.

3.4.2 Eco-Toilet Incentive Program Funding

On July 16th, 2012, the Falmouth Board of Selectmen approved $80,000 for Group I of the Eco-Toilet Incentive Program. This demonstration envisions incentive payments of up to $5,000 for a home or business in Falmouth that participates as well as a septic system pump-out valued at approximately $300. This payment comes after all permitting has occurred, and the full cost of installation has been paid by the property owner. The WQMC expects approximately 16 participants in this first effort to quantify the cost, feasibility, and actual nitrogen removal capacity of both composting and urine-diverting toilet technologies. Participants must install eco-toilets in all of their bathrooms, and agree to a year-long testing program through the BCDHE. Participants must also agree to several requirements that are outlined in the Eco-Toilet Incentive Program application forms (Appendix 3-5). Going forward, the WQMC expects to request a release of additional funds by the Board of Selectmen to enable incentive payments to additional participants in the demonstration.

3.4.3 Public Outreach/Enrollment

A significant public education campaign was launched to inform the community about the potential benefits of eco-toilets. Part of this effort began as part of the campaign to promote passage of funding for the demonstration of alternatives at the Spring 2011 Town Meeting. With the passage of Article 17, the WQMC was formed and included representatives of the community group interested in promoting this option. The following lists the broad approach taken to public education:

- Workshops.
- Flyer in the Water Bill.
- Attendance at community events (2012 concert, Falmouth Farmers Market).
- Public Meetings.
- Eco-Toilet Conference sponsored by the WQMC, Waquoit Bay National Estuarine Research Reserve, The Green Center, and the Cape Cod Commission.
- Ongoing press coverage.

An initial list of interested citizens came out of early meetings and discussions. Additional public outreach broadened this list to over 150 residents. All were contacted to discuss the opportunity to install eco-toilets in their home and be a part of the demonstration. Over 40 residents were interested enough to schedule a site visit. During this site visit, a detailed analysis of the feasible eco-toilet options was completed. Pricing for the possible options was also provided.

A critical component to the success of the demonstration's enrollment is the contribution made by the Cape Cod Eco-Toilet Center in Falmouth. This facility houses almost all of the models being considered by potential participants. In the same way that homeowners visit design showrooms to help select bathroom fixtures for conventional remodeling projects, the Eco-Toilet Center enables a potential participant to see eco-toilets in real life. In addition, the Center offers tours and informational sessions weekly. Every participant in Group I of Falmouth's Eco-Toilet Incentive Program visited the Center prior to making the final decision to proceed with an installation.

3.4.4 Implementation: Permitting and Other Issues

In most cases, installing composting and urine diverting toilets in existing homes requires modifications to existing plumbing and venting. Building permits must be granted for these changes, and plumbing work must be code-compliant and be done by a licensed plumber. Any plumbing fixture installed in Massachusetts must have a Product Acceptance number. Several composting toilets have this approval.

However, urine-diverting fixtures, source separators (Aquatron), and other pilot-stage urine-diverting toilet technologies do not currently have a Product Acceptance number from the State Board of Plumbers and Gas Fitters, and are therefore illegal to install in the state. This was identified as a significant barrier to implementation. Science Wares worked with the local plumbing inspector, State plumbing board, and BCDHE to obtain a variance for Test Site Status for up to 40 test sites to enable urine-diverting fixtures to be installed. This was granted at a regular meeting of the State Board of Plumbers and Gas Fitters on March 27th, 2013 and paved the way for significantly more installations than would have been feasible with composting toilets alone. The State approval for an entire class of eco-toilets overcame a significant obstacle.

Another obstacle to the implementation of the Eco-Toilet Incentive Program has been overcome. At the inception of the demonstration, there were no local installers with expertise in all permitted composting systems and no local plumbers were familiar with urine-diverting fixtures. Each manufacturer of composting systems has a different sales model. Two use direct sales to end users through hardware stores and large distributers of building supplies. However, local stores did not already carry these eco-toilets. A different manufacturer has an online form, where a property owner can fill in baseline information and receive a materials quote electronically. The lack of a local presence, and the focus on the "do-it-yourself" market was not a good fit for the property owners interested in participating in the demonstration. Only one manufacturer has a regional sales representative who is able to conduct site visits. This representative was not in a position to give advice on all the possible eco-toilet configurations.

As part of the implementation of the demonstration, regular contact with manufacturers of composting toilets with Product Acceptance is maintained to encourage a local presence. A local hardware store now carries the products of one manufacturer and has the units displayed in the window of their Main Street location. Other manufacturers now communicate directly with potential participants, pricing out their products. Education of local plumbers about urine-diverting fixtures continues.

Selecting the best eco-toilet system is an iterative process involving the physical constraints of the built environment as well as cost considerations. A site visit from someone capable of making these kinds of assessments is a critical component for many people, providing unbiased information on the full-range of eco-toilet configurations. Growing the eco-toilet industry on Cape Cod is the ultimate goal. Until that industry has robust representation, the demonstration will continue to provide property owners with information on all systems that have Product Acceptance or Test Site Status.

3.4.5 Eco-Toilet Incentive Program Statistics as of June 30, 2013

Number of people contacted: 152

Number of people with site visits: 44

Number of people who have agreed to participate:.. 21

- Installations permitted through Board of Health:.................................4
- Permits completed but not submitted: 1
- Participants working through final details of installation: 11
- Participants who are beginning to work through installation details:....5

Number of people who have asked to be contacted later—timing
is not good now, but is expected to be better at a later time: 10

Number of near-installations (waiting for final plumbing inspection): 3

Number of pre-installation sites sampled (BCDHE): 3

Types of installations/eco-toilets chosen:

Full range, including central composters, self-contained units, urine-diverting fixtures

3.4.6 Next Steps

- Continue to work with Group I participants to specify and permit installations.
- Begin post-installation sampling (BCDHE).
- Process incentive payments.
- Analyze installation cost data as it becomes available as part of the incentive payment applications.
- Review sampling data as it becomes available, discuss with regulatory agencies.
- Assess installations.
- Evaluate the need for additional installations and incentive authorization (beyond first $80,000).
- Continue to develop a database of potential participants.
- Work with other communities to include their installations in the database.
- Begin planning for residuals collection, processing, and end-use marketing.
- Coordinate with others involved in testing the attenuation of Contaminants of Emerging Concern (CEC) in eco-toilets.

3.4.7 Technology Overview

This section describes the range of eco-toilets that are part of Falmouth's Eco-Toilet Incentive Program. Eco-toilets are to be installed only in a household or small business with a standard septic system.

Installation, operation, and maintenance manuals for each of the eco-toilets described below are in Appendix 3-5. These manuals provide details from each manufacturer on their products.

The energy use of the fans and heaters associated with each individual composting eco-toilet ranges from 120 to 540 watt-hours per day, or between 44 and 197 kilowatt-hours per year. Urine-diverting fixtures that discharge into a holding tank do not have any fans/heaters associated with them at present. However, the energy used to transport the stored urine should be considered. This will vary by distance. Product information, as well as the energy associated with different reuse end-points for the urine will be verified during the demonstration. This information will also be used as part of the comparative energy analysis for each wastewater treatment solution. Composting and urine diverting systems may be combined, and remote composting systems may be combined with stand-alone composting toilets.

3.4.7.1 Self-Contained Toilets

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

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

- Envirolet/Santerra Green: A stand-alone composting toilet in which urine and feces are composted in the same built-in rotary composting unit. Compost is emptied by hand, typically at intervals of four to six months, depending on use. Various models are available. For more information, see www.envirolet.com and Appendix 3-5.

All Envirolet 120VAC electric models use a maximum of 540 watt-hours per day.

120VAC models have two 20W fans and one 500W heater. According to the manufacturer, the fans should be operated all of the time when the system is in use. For optimum performance, the fans should also be running when the unit is not in use for up to two weeks. When the system is in "Fans Only" mode, the power consumption is 40W (two fans x 20W each). The 500W heater should be run when the system is in use, or a Drain Kit must be installed. The heater is thermostatically controlled to operate approximately 25- to 30-percent of the time. Therefore, run-time is approximately six hours a day.

- Sun Mar self-contained unit: A stand-alone composting toilet in which urine and feces are composted in the same built-in rotary composting unit (biochamber). Compost is emptied by hand, typically at intervals of four to six months, depending on use. Various models are available. For more information, see www.sun-mar.com and Appendix 3-5. 125 watts/day (includes fan and heater, and assumes 50-percent operation)
- BioLet: A stand-alone composting toilet in which urine and feces are composted in the same built-in rotary composting unit. Compost is emptied by hand at intervals. Various models are available. For more information, see www.biolet.com, and Appendix 3-5.

The following units have Test Site Status from the Massachusetts State Board of Plumbers and Gas Fitters for the demonstration. Up to 40 test sites have been authorized.

- Separett: A stand-alone urine diverting toilet normally set up for hand disposal of both urine and feces that must/will be composted outside the home. The urine chamber of the Separett may also be connected to a large urine tank. For more information, see www.separett.com, and Appendix 3-5.

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

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

3.4.7.2 Composting Toilet Systems with Remote Composting Bin(s)

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

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

- Advanced Composting Systems (ACS)/Phoenix: Up to four toilets may be connected to a single composting container. Several types of toilet may be connected to the central composting container. Normally the toilet fixture will be a single chamber type with a wide opening through which both urine and feces are transferred to the composting container and processed into compost. A urine diverting dry toilet may also be used with a separate connection to a large urine storage tank. In difficult situations where a toilet is too far away from the composting container, a foam flush toilet may be used. A dedicated vent stack must be installed. For more information see www.compostingtoilet.com and Appendix 3-5. The system requires a 5-watt fan that runs 24 hours/day = 120 watt-hours per day.
- Clivus Multrim: The manufacturer recommends that only single chamber toilets that transfer both urine and feces to the central processing unit be used. Clivus Multrim markets its own foam-flush toilet (Neptune) for situations where the toilet is too far away from the composting chamber for gravity discharge to the compost bin. A dedicated vent stack must be installed. For more information see www.clivusmultrum.com and Appendix 3-5. The system requires a 5-watt fan that runs 24 hours/day = 120 watt-hours per day.
- Envirolet/Santerra Green Central Units: Both direct-discharge dry toilets, as well as vacuum flush units are available. Several toilets may be connected to a single composting container. A high capacity double tank is also available. FlushSmart™ VF™ is a vacuum flush and composting toilet system combination that is recommended for installations on rock or with little or no room below, basements, garages, workshops, pool cabanas, yurts, and applications where a smaller toilet is needed or desired. A dedicated vent stack must be installed. For more information, see www.envirolet.com and Appendix 3-5. Central models use a maximum of 540W per day. A detailed description is provided in the technical description of the self-contained unit.
- Sun Mar Central Units: Several dry toilets may be connected to a single composting container. For locations where a direct gravity feed is not feasible, the manufacturer recommends use of a Sealand 510 or 511 marine toilets. This is an ultra-low flush toilet that may be installed either directly above or up to 15-feet away from the central composting unit. A dedicated vent stack must be installed. For more information, see www.sun-mar.com and Appendix 3-5.125 watts/day (includes fan and heater, and assumes 50-percent operation).
- Eco-Tech Carousel: Several types of composting toilets, including urine diverting dry toilets and foam flush toilets, may be connected to this set of bins in a rotating chamber. The urine diverting toilet will require connection to a large urine tank and the foam flush toilet must be connected to the household water line. There are two sizes of rotating chamber and each rotating chamber has four separate bins, only one of which is in use at a time. For more information, see www.ecological-engineering.com/carousel.html and Appendix 3-5. This system requires a 5-watt fan that runs 24 hours/day = 120 watt-hours per day.

The following unit has Test Site Status from the Massachusetts State Board of Plumbers and Gas Fitters for the demonstration. Up to 40 test sites have been authorized.

- Full Circle: A 55 gallon wheelie bin is connected to a single dry composting fixture with urine-diversion. The bin collects feces for composting, with a separate storage container for urine. Each bin serves only one toilet. A dedicated vent stack must be installed for each bin. For more information, see www.fullcirclecompost.org and Appendix 3-5.

3.4.7.3 Summary of the Toilet Fixtures used with Composting Systems

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

Dry composting toilets (with and without urine-diversion) are installed as part of a composting system. See manufacturer's recommendations for dry composting fixtures that are compatible.

<u>Ultra-low Flush Composting Toilets:</u> The Sealand 510 and 511 models are the only examples mentioned, and they are recommended for use on Sun Mar central units where toilets must be offset from the central unit.

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

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

3.4.7.4 Urine-Diverting Flush Toilet Systems

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

- Dubbletten "double flush" toilet: The urine and feces/toilet paper chambers flush separately, the urine chamber with very little water. The user need not flush the urine chamber after every use. To save water, it is recommended that paper used after urinating is disposed of in a separate receptacle near the toilet, and not flushed. For more information, see www.dubbletten.nu and Appendix 3-5.

- Wostman Eco-Flush toilet: The urine and feces/toilet paper chambers flush separately, the urine chamber with very little water. The user need not flush the urine chamber after every use. To save water, it is recommended that paper used after urinating is disposed of in a separate receptacle near the toilet, and not flushed. For more information, see http://wostman.se/en/ and Appendix 3-5.
- Aquatron Centrifuge composting system: Wastewater from the feces/toilet paper chamber of one or more urine diverting toilets passes through a gravity-driven centrifuge that separates solid matter from wastewater going to the septic system. Solid matter drops out into a composting container. The Aquatron centrifuge may be used with any flush toilet, but for our demonstration it will be used with urine diverting flush toilets such as the Dubbletten or Wostmann toilets. For more information, see www.aquatron.se/index-2.php and Appendix 3-5.

<u>Waterless (or very low flush urinals):</u> There are many models that may be used in conjunction with UD toilets in any UD system. Any fixture that has Product Acceptance may be installed as part of the demonstration.

3.4.7.5 Urine Tanks Used with Urine-Diverting Toilets and Waterless or Ultra-Low Water Urinals

Any MassDEP-approved septic tank may be installed as part of the demonstration to hold urine. Tanks with a 500-gallon capacity are being used in the demonstration.

3.4.8 Site Installation Review/Checklist (to be completed for each installation)

The following information will be developed for each installation and is expected to be formatted in a checklist.

Pre-installation Information:

- Number/type/location of each toilet (floor plan)
- Type and size of septic system drain-field
- Type of home/lot size
- Number of occupants and days per year of occupancy
- Average nitrogen in septic tank effluent pre-installation of eco-toilet(s)

Purchasing details:

- Manufacturer/Make/Model
- Major additional components
- Local vendor
- Materials costs (delivered prices)

Current permitting status:

- Product Acceptance versus Variance/Test Site Status
- Falmouth BOH and local issues

Installation/Engineering Details:

- Space required
- Piping and venting
- Electrical connections
- Handling of excess liquid
- Installation cost
- Noteworthy complications

Installation/Engineering details for urine collection and storage system (if applicable):

- Space required
- Piping and venting
- Electrical connections
- Handling of excess liquid
- Cost (materials and labor)
- Noteworthy complications

Records of use, cleaning, maintenance and repair, and emptying residuals:

- Use
- Cleaning
- Maintenance and repair
- Removal of residuals
- Handling of urine
- Noteworthy issues and complications that have emerged from pilot study

Sustainability:

- Energy use
- Reduction in water use
- Nutrient capture
- Resistance to flooding

Effects on the operation of other elements of the waste system:

- Compatibility with grey water treatment systems
- Compatibility with residuals collection systems
- Life and health of septic system
- Other documentation elements

- Any special requirements
- Total cost summary

As with the other demonstration projects, if this method of wastewater management proves feasible and acceptable in the future and is less expensive, the CWMP will be modified through Adaptive Management to proceed with its large-scale implementation. To date $190,000 has been committed to the first phase of this demonstration project. A balance of $310,000 remains in Article 17 for additional phases.

3.5 Permeable Reactive Barriers

3.5.1 Overview of Permeable Reactive Barriers

Permeable Reactive Barriers (PRB) were described in Chapter 9 of the 2007 Alternatives Screening Analysis Report (attached in Appendix 2-6). At that time they were called Nitrate Barrier Walls and were identified as a possible method to treat the nitrogen in groundwater before it recharges to the marine waters. That nitrogen could be from any number of sources: septic systems, fertilizers, stormwater, atmospheric deposition, etc.

The concept involved the construction of a “permeable wall” of reactive material that would allow the groundwater to flow through but would react with the nitrate in the groundwater and convert it to nitrogen gas. In 2007, the technology was experimental and the reactive material was a patented media called NITREX™. This material would reduce the dissolved oxygen in the groundwater and supply organic carbon to a level at which biological denitrification could occur. The barrier would need to be deep enough to prevent any nitrogen-laden groundwater from flowing under the wall. If the technology were used alone to help an estuary meet its TMDL, the barrier would need to be constructed the full length of the peninsulas bordering the estuary.

In 2007, the technology was being studied by a group of scientists led by Dr. Joseph Vallino and Dr. Kenneth Foreman of the Marine Biological Laboratory. Two pilot studies in the Waquoit watershed were under way: a 50-foot barrier on a beach, and a shorter barrier on a private lot bordering the estuary. Several issues had emerged:

1. Effects of salt water flooding of the NITREX™ media during storms due to proximity to the marine water.
2. Feasibility of installing the wall deep enough to prevent nitrogen-laden groundwater from flowing under the wall.
3. A need for full understanding of the nitrogen removal mechanism occurring in the barrier.
4. A need for long-term monitoring both upstream and downstream of the barrier to measure results.
5. Permitting issues because of the proximity to lands subject to the Wetlands Protection Act.
6. Problems of access to private property for either installation or monitoring.

The assessment in the Alternatives Screening Analysis Report was that this method was not ready for full-scale application due to technical issues and regulatory feasibility, and it was screened out. In 2010, the CWMP Review Committee re-examined the technical and regulatory issues, and the current monitoring data showing continued success in removing nitrate from the groundwater. The Committee noted that the patent on the reactive media had expired, that carbon sources such a woodchips could be tried, and that a demonstration project could be designed to address the issues that had been raised. The Board of Selectmen adopted this recommendation and PRB’s were added back into the mix of possible technologies described in the Draft Report and Notice of Project Change. Town Meeting agreed in April 2011 to fund a possible demonstration project by passing Article 17, a bond issue, and the voters agreed.

3.5.2 Current Status of PRB Demonstration Project

In 2012, the WQMC, working through its PRB subcommittee, developed a request for proposals to hire an engineering firm to assist in the development of the PRB demonstration project. The scope of work included:

1. Research existing PRB knowledge base.
2. Identify anticipated permitting requirements related to the use of PRBs as a long-term municipal wastewater solution.
3. Identify potential impact to the environment down-gradient of a PRB.
4. Evaluate sub-watershed areas for a PRB in the selected estuarine watersheds [West Falmouth Harbor Watershed, and all the watersheds in the High Priority Nitrogen Management Area].
5. Identify up to two dozen potential PRB locations in the sub-areas.
6. Define permitting requirements and other neighborhood factors for each selected sub-area.
7. Screen down to five locations for consideration for a full demonstration, one in West Falmouth and the remaining four in the East Falmouth coastal area; prepare a preliminary design and cost estimate for each.
8. Recommend two sites for PRB demonstration projects, one in West Falmouth and one in East Falmouth.

In 2013 the Request for Proposals was issued, and CDM Smith was awarded the contract. Technical Memoranda Nos. 1 and 5a can be found in Appendix 3-6. As of June 30, 2013, the contractor has screened down to one location in West Falmouth called Site 5, and two promising locations in East Falmouth.

CDM Smith has been authorized to proceed with preliminary design for a PRB demonstration installation at Site 5 in West Falmouth and Site 4b in Seacoast Shores. Site 4b was the High Priority Mitigation Area because groundwater data was already available from the Cape Cod Commission, and the USGS is currently gathering more data in the area.

Engineering for the preliminary design of the PRB Demonstration Project cost $185,000. A balance of $65,000 remains in Article 17 allocated to PRBs. The estimated capital cost to construct one or two PRBs should be known by the end of 2013. This cost could be included in the bond issue planned for the Spring 2014 Town Meeting.

3.6 Stormwater Management for the Little Pond Watershed

The stormwater nitrogen loadings to the South Coast are summarized below:

Table 3-1 Summary of Stormwater Nitrogen Loadings to the Planning Area Watershed

Estuary	Nitrogen Loading (kg/yr)
Little Pond	500
Great Pond	2,300
Green Pond	700
Bournes Pond	500
Waquoit West	3,300
Waquoit East	2,900

Reference: Data from Table 1 of March 5, 2008 Technical Memorandum by Stearns & Wheler as attached in Appendix 3-7.

The nitrogen loading associated with road and roof runoff is based on the following factors summarized in the MEP Technical Reports:

- Stormwater flow and recharge from impervious surfaces is developed based on a recharge rate of 40-inches per year.
- Nitrogen loads to the groundwater system from stormwater are based on the following concentrations:
  - 1.5 mg/L for road runoff
  - 0.75 mg/L for roof runoff

A summary of all the nitrogen loadings to the watersheds is attached in Appendix 3-7 with figures illustrating the percent contributed from the various sources. The figures show that stormwater runoff contributes 5- to 9-percent of the controllable nitrogen sources entering the Little, Great, Green, and Bournes Ponds watersheds. The stormwater loading factors and loading values may be considered high based on the following:

- The loading values assume that all of the nitrogen in the runoff is transported to the groundwater system.
- No nitrogen removal (attenuation) credit is given for nitrogen uptake by vegetated areas.
- No nitrogen removal credit is given for nitrogen attenuation by stormwater leaching systems.

It is also noted that there is no practical way to monitor if the stormwater nitrogen loads calculated by MEP are really occurring, and there will be no way to monitor if there are quantified improvements with future stormwater management procedures. As a result, there may not be the ability to quantitatively utilize stormwater management to meet a nitrogen TMDL. Even with the above stated problem of quantitatively managing stormwater nitrogen loading, the Town is taking steps to improve stormwater controls for nitrogen management.

3.6.1 Summary of Previous Evaluations of Current Stormwater Surface Discharges

In the past, the main focus of stormwater management was to eliminate direct discharges to surface waters in order to reduce sediment and fecal coliform loading to the surface waters. A draft final report was developed in October 1995 by Muramoto and Polloni Wetland Studies titled "Inventory of Falmouth's Wetlands Damaged by Direct Road Runoff conducted for the Town of Falmouth." This report identified 117 potential direct discharge sites and prioritized 20 sites based on discussions with Town personnel and remediation feasibility (see Appendix 3-7). In addition to this study, the Town Department of Public Works (DPW) through the Town Engineering Department maintains an "Inventory of Direct Stormwater Discharges" through its Coastal Drainage Program which tracks dates of completion as they occur (see Appendix 3-7). The DPW also maintains the DPW Drainage List which tracks where improvements to the drainage collection systems are necessary and when they are made (see Appendix 3-7). The Town also holds a National Pollutant Discharge Evaluation System (NPDES) Phase II Stormwater General Permit which is designed to prevent harmful pollutants from entering local water bodies.

Falmouth's Engineering Department is responsible for implementing the Phase II requirements for the Town's NPDES permit and has been moving forward with compliance. The Engineering Division maintains an active list of drainage concerns for this permit. Each site is evaluated for repair, including best management practices (BMP's), water quality, and accessibility for maintenance. Work is ongoing to correct the stormwater issues. A copy of a recent annual report for this permit is attached in Appendix 3-7, and actions related to Little Pond are summarized below.

3.6.2 Little Pond Stormwater Control

Several key aspects of the NPDES compliance program that relate directly to Little Pond watershed include:

- Development of an all-inclusive Public Works Stormwater Regulation including NPDES compliance requirements. This regulation was developed by the Engineering Department and is currently under review by the Board of Selectmen, with adoption expected in FY2014.
- Updating the outfall maps Town-wide and the Little Pond watershed in particular. Information on structures, connections between structures, and stormwater contribution areas are being collected and mapped. Field inspections include identifying any illicit discharges such as basement sump pumps draining to catch basins. The current focus is identifying outfalls and roadway runoff areas that impact Little Pond directly.
- Ongoing Public Education campaign for the Town, including the Little Pond watershed. The following outreach tasks have been accomplished by working with an Americorps Cape Cod employee:
  - Initiate a storm drain marker installation program within the Lower Little Pond watershed. Storm drain markers stating "NO DUMPING, DRAINS TO WATERWAY" have been installed.
  - Develop and initiate a storm drain stenciling program in the Lower Little Pond watershed, where there are no curbs to install the storm drain markers.
  - Design, print, and distribute door hangers aimed at public education to reduce fertilizer use, car washing, pet waste, and littering.
  - Develop a "Homeowner Stormwater Education Kit" containing information on composting, stormwater education, and homeowner tips. The kit will be distributed in the summer of 2013 to sites within the Lower Little Pond watershed.
  - Ongoing evaluation, review, and update of the current Public Outreach and Participation Program.

- The Town Driveway Permit forms have been modified to include NPDES stormwater requirements. Modifications include:
  - Statement "No driveway shall be constructed directing stormwater onto roadways."
  - Bonding of permits ensuring all site work is constructed according to the driveway permit and attachments.
- A Stormwater Committee (Selectmen/DPW) has been formed. Monthly meetings are held regarding improvement of all coastal ponds and reduction in nitrogen. Several community groups are moving forward with seeking Town funding and grants to improve the salt and fresh waters of Falmouth.
- Street cleaning is performed in the spring after snow removal operations, and in the fall after the hurricane and storm season. Main arteries are swept on a weekly basis. A catch basin cleaning truck and crew has been dedicated to full time basin cleaning from April to October. The Town no longer applies sand/salt mixtures to the roadways during the winter season. The roads are pretreated with a salt brine mixture that is applied prior to inclement weather. Street sweeping and catch basin sediment removal amounts are tracked in an asset management program.

Preliminary evaluations have begun to determine appropriate BMPs for the Little Pond watershed, such as bio-retention. This evaluation process is being informed by EPA's Green Infrastructure objectives and other current research results such as University of New Hampshire Stormwater Center (UNHSC) project to optimize nitrogen removal from stormwater treatment systems. The Town, through its Engineering Department, other appropriate departments and boards, as well as technical consultants, will pursue feasible BMP solutions as part of the sewer construction for this watershed. This analysis will include:

- Summarize findings of previous studies, reports, and information related to the NPDES Phase II requirements.
- Coordinate with the Engineering Department and USEPA to gain USEPA support in remediation efforts.
- Define New Stormwater Management Project for Little Pond including:
  - Identify additional needed structural controls including location and expected effectiveness.
  - Identify new non-structural controls such as by-laws, ordinances, etc., and coordination with local stakeholders to gain support.
  - Evaluate advantages and disadvantages of these controls with respect to Little Pond.
  - Estimate expected nitrogen reduction.
  - Develop conceptual designs for each with capital and O&M costs.
  - Define an implementation plan for each.
  - Coordinate with stakeholders to gain support.
  - Coordinate with MassDEP to define needed monitoring and reporting for Little Pond TMDL compliance.
  - Summarize findings for Town and stakeholder review.

The intent of the initial phase of this analysis is to identify and evaluate the full range of stormwater management technologies for nitrogen reduction that are appropriate at Little Pond. These alternative methods will then be compared to other methods, with respect to feasibility and cost and incorporated into the CWMP through Adaptive Management.

In addition, the Falmouth Conservation Commission is revising their Stormwater Regulations. Nitrogen-reduction BMP requirements will be part of this update. Treatment BMPs such as bioretention areas, rain gardens, constructed stormwater wetlands, extended dry detention basins, sand and organic filters, and wet basins are being reviewed for appropriateness. Examples of Low Impact Development (LID) include porous pavement sidewalks and swales, bioretention parking dividers, and permeable paving. Where space limitations exist, infiltration BMPs such as infiltration basins, infiltration trenches, leaching catch basins, and subsurface structures should be incorporated into the design where possible to mitigate stormwater runoff.

3.6.3 Further Recommendations for Stormwater Management

Stormwater management is a Town-wide issue and requires action by both the government and residents. In addition to the Conservation Commission, other Town departments can assist in stormwater management by reviewing their current bylaws for stormwater management related sections, and requiring that new development or any areas incentivized for planned growth utilize stormwater BMPs and integrate LID features into designs prior to local approval. Homeowners need to provide stormwater management at their respective properties. Small changes such as directing rain runoff from roofs and driveways to lawn areas or other biologically active areas such as gardens or flowerbeds can benefit the environment. Rain barrels can also be utilized to store runoff from roofs for use in watering landscaping or other non-potable activities. Driveway runoff can be mitigated through the use of stone, porous pavement, or by installing vegetated filter strips. It is intended that the Conservation Commission regulations will become a template for a Town-wide bylaw to prevent stormwater pollutants from entering the Town's estuaries.

3.7 Development and Recent Town Passage of a Comprehensive Nitrogen Control Bylaw (for fertilizer)

The extent of nitrogen loading from fertilizer was identified in MEP Technical Reports and subsequent TMDL reports prepared by MassDEP for Little Pond, Great Pond, Green Pond, Bournes Pond, and the Waquoit East and West watersheds. The existing fertilizer nitrogen loads to these watersheds are summarized below:

Table 3-2 Summary of Fertilizer Nitrogen Loadings to the Planning Area

Estuary	Nitrogen Loading (kg/yr)
Little Pond	700
Great Pond	1,700
Green Pond	900
Bournes Pond	500
Waquoit Bay East	900
Waquoit Bay West	2000

Based on information included in Table 1 of the February 29, 2008 Technical Memorandum by Stearns and Wheler as attached in Appendix 3-8.

Fertilizer contributes 5- to 10-percent of the controllable nitrogen sources entering these watersheds. A summary of the nitrogen loads to the watersheds from all sources is attached in Appendix 3-8, and includes figures that illustrate percent contributions from various sources.

The application of too much fertilizer is a problem throughout Falmouth's south coast watersheds. Education on proper fertilizer types, application techniques, and frequency of use can help reduce over-fertilization, which is the most common cause of fertilizer leaching into the groundwater system. From 2002 through 2005, the Falmouth Ashumet Plume Committee initiated and ran a significant public education campaign entitled Falmouth Friendly Lawns (FFL). This group investigated ways that fertilizers could be managed and promoted more appropriate lawn care. The campaign rewarded the organizations and individuals that followed the FFL guidelines and limited their use of fertilizer nitrogen. The FFL Program certified approximately 100 participants with public-relations and "honor roll" events. In 2006, the Falmouth Ashumet Plume Committee recommended that the Town take over the FFL campaign, estimating that the cost of administering the current campaign would be approximately $80,000 to $134,000 for a 3-year period depending on the number of new initiatives added. Due to financial constraints, the Town did not take over the program.

As part of developing this CWMP, both voluntary programs such as Falmouth Friendly Lawns, as well regulatory approaches were carefully evaluated. A Fertilizer Options Analysis Matrix was prepared to summarize the findings of several reports completed for other coastal communities on this topic. This Matrix is in Appendix 3-8. The following two-pronged approach was selected for implementation:

- Town adoption of a Nitrogen Control Bylaw to regulate fertilizer use.
- Educational campaign to support the Nitrogen Control Bylaw coordinated through citizens' groups.

As part of the CWMP process, the Town determined that adoption of a Nitrogen Control Bylaw (for fertilizer) would be the most effective approach to limiting nitrogen from fertilizer applications, because it would both create an enforceable regulation and it would galvanize public education campaigns. Another advantage of this approach is the provision of explicit fertilization limits and clear standards for fertilizer use in Falmouth's watersheds. As is the case with most of Falmouth's bylaws, enforcement will be complaints-driven. The Town expects this approach to be effective. The main challenge to the success of the Town's approach is establishing a method to monitor its efficacy. MassDEP indicates that it would support a bylaw but would only be able to provide a nitrogen reduction credit if it could be monitored or verified. This dialogue occurred during the 2001 Falmouth Wastewater Planning Project evaluations for the West Falmouth Harbor watershed.

Given the fact that a Nitrogen Control Bylaw coupled with local educational efforts will lead to the removal of some portion of the controllable watershed load of nitrogen attributed to fertilizer, the WQMC authored a Nitrogen Control Bylaw for fertilizer. Fall 2012 Town Meeting adopted this Town-wide bylaw. This bylaw prohibits the application of nitrogen within 100-feet of resource areas as defined in Falmouth's Wetlands Regulations, FWR 10.02 (1)(a - d), as well as on impervious surfaces. The bylaw also prohibits the application of fertilizer anywhere in Town from October 16th to April 14th. During the growing season of April 15th to October 15th, fertilizer application is banned during heavy rain. There are exceptions for agriculture and horticulture. Regarding golf courses, on greens and fairways only, no more than one pound of nitrogen per 1,000 square feet may be applied over the entire growing season. Furthermore, 85-percent or more of this fertilizer must be in an organic, slow-release, water-insoluble form on greens and fairways only. There are also allowances for the application of organic constituents applied to improve the physical condition of the soil, and the establishment of turf. Enforcement is through the Department of Marine and Environmental Services (a merging of the Harbormaster's Office and the Department of Natural Resources). A copy of this Nitrogen Control Bylaw can be found in Appendix 3-8.

On May 15, 2013, the Attorney General disapproved the new bylaw stating that the Legislature has vested the regulatory authority over fertilizers with the Department of Agricultural Resources. The Town's legislative delegation filed corrective legislation that recently passed, reinstating the Town's Nitrogen Control Bylaw.

Falmouth Association Concerned with Estuaries and Saltponds (FACES), an active local citizen's group, has offered to assist with a public outreach campaign. This education campaign will be patterned after the FFL program. To initiate the educational component, past participants in the FFL will be contacted, and additional participants sought. Working through the Chamber of Commerce and trade associations for the lawn care and turf management industry, best practices for meeting the regulations in the bylaw will be explained. In addition, point-of-sale promotions to increase public and business awareness of the new bylaw will be done. An outreach campaign to broaden volunteer involvement will be formalized. Future educational initiatives will focus on landscape design practices that minimize negative environmental impacts. Certain landscape design practices can reduce fertilizer needs, reduce impervious area, and increase runoff control. Recommended landscape practices will include pesticide and fertilizer alternatives, composting, and low maintenance plants.

A notable difference between this new initiative and the FFL program is that with a Nitrogen Control Bylaw in place, the program will not be purely voluntary. The Town believes that regulation coupled with education will reduce the nitrogen-loading attributable to fertilizer use in a way that is measurable and verifiable. The Town is actively implementing this approach.

3.8 Information Gathering on Individual-Property and Clustered Nitrogen-Removal Septic Systems

Technical aspects of on-site and cluster denitrifying septic systems have been detailed in Chapter 7 of the 2007 Alternatives Screening Analysis Report (attached in Appendix 2-6). These systems are closely regulated by MassDEP as part of their Title 5 regulations. This Report states that "decentralized treatment alternatives approved by the MassDEP as part of their innovative and alternative technology program can be used for areas outside the sewer area as currently allowed by MassDEP regulations." It is now noted that recent test data (data up to 2012) from several newer denitrifying technologies show nitrogen removal greater than 90-percent. To meet TMDL thresholds in the Town's impaired estuaries, the Town wants to implement the full range of acceptable technologies that cost-effectively remove nitrogen adequately. As such, denitrifying septic technologies will be investigated further and the cost per pound of nitrogen removal will be calculated. Issues surrounding ongoing performance monitoring, maintenance, and permitting will also be addressed. As advantageous technologies are identified, they will be incorporated into the CWMP through Adaptive Management. The WQMC has developed a Roadmap to assist in the identification of promising technologies. This Roadmap includes:

3.8.1 Survey Existing Knowledge Base for Both Individual as Well as Cluster Denitrifying Septic Systems (DSS)

- Coordinate with the Oyster Pond CWMP process that is currently underway to avoid duplication of effort. This CWMP project includes technologies that are approvable in Massachusetts. Promising technologies that have a short pathway to regulatory approval may also be discussed.
- Summarize results of key prior studies, including:
  - Suffolk County Department of Health Services (SCDHS) Innovative/Alternative On-Site Sewage Disposal Systems (OSDS) Study: Suffolk County has begun a formal evaluation of innovative/alternative onsite sewage disposal systems capable of denitrification, ranging from individual home systems to small plants capable of servicing up to 100 dwelling units (30,000 gallons per day). The study is being performed by a consultant, Holzmacher, McLendon, & Murrell, P.C. (H2M), The study is expected to be completed by December 2013.
  - Environmental Protection Agency, Guidance for Federal Land Management in Chesapeake Bay Watershed, Chapter 6: Decentralized Water Treatment Systems (May 12, 2010).
  - Maryland Bay Restoration Fund (BRF): Best Available Technology for Removing Nitrogen from Onsite Systems http://www.mde.state.md.us/programs/Water/BayRestorationFund/OnsiteDisposalSystems/Pages/Water/cbwrf/osds/brf_bat.aspx
  - Report to New Jersey Pinelands Commission on Pilot Program (November 2009).
  - Barnstable County Department of Health and Environment: Innovative and Alternative Onsite Septic Systems Performance, 1999-2007.
  - Final Report: La Pine National Demonstration Project, 1995–2005.

3.8.2 Characterize Performance of 15 DSS Systems

Characterize the performance of the 15 DSS systems that have received nitrogen removal credit (as listed by MassDEP http://www.mass.gov/dep/water/wastewater/techsum.htm). Include relevant information from Chapter 7 of Falmouth's Alternatives Screening Analysis Report (Stearns and Wheeler). This effort should include:

- Price quotes from vendors.
- Other reported performance and price points.

- Input from Barnstable County Department of Health and Environment.
- Discussions with Cape-wide engineering firms to learn of practical experience with DSS.
- Identification of installations that are required to achieve near 5 mg/L nitrogen removal or better.
- Site visits to operational DSS systems that achieve 5 mg/L nitrogen removal and that are reasonably nearby.
- Other independent research.

3.8.3 Prepare Comprehensive List of Commercial Denitrifying Septic Systems

Prepare a comprehensive list of commercial or near commercial denitrifying septic systems that have some level of DEP approval and/or achieve nitrogen removal rates down to treated effluent levels of near 5 mg/L or less and are currently in operation (either commercially or at test centers) and characterize their efficacy in the long term. Estimate capital and operating cost per unit and cost per pound of nitrogen removed over the projected useful life of the DSS (either individual or cluster). Discuss aspects of monitoring and operation that are expected to be required for long-term operation at desired nitrogen removal thresholds.

- Identify permitting issues and any other barriers related to implementation for above technologies.
- Describe monitoring protocols that have been developed for installed DSS.
- Note the ability of any DSS to sequester phosphorus for reuse or treat chemicals of emerging concern. Use information from BCDHE publication entitled "Contaminants of Emerging Concern from Onsite Septic Systems". Chapter 7 of Falmouth's Alternatives Screening Analysis Report (Stearns and Wheeler) listed inability to remove phosphorus and CECs as a shortcoming of DSS systems.

3.8.4 Present this Information in a Summary Table for Consideration of Next Steps

These efforts are ongoing and will be completed within the next 12 months.

3.9 Ocean Outfall Evaluations

3.9.1 Overview Discussion on an Ocean Outfall for Falmouth

Falmouth lies on the southern, down-gradient side of a sole source aquifer, the Sagamore Lens. This aquifer feeds multiple Falmouth watersheds that flow to coastal embayments on Buzzards Bay and Vineyard and Nantucket Sounds. This geology poses the greatest challenge to addressing the nutrient levels in our coastal ponds—where to discharge treated wastewater in our upper watersheds so that it does not affect freshwater and coastal ponds down gradient. We all now appreciate what happened to West Falmouth Harbor when secondary treated wastewater from our main treatment plant was discharged to groundwater in the West Falmouth Harbor watershed. As part of our current wastewater planning process (discussed later in the following Chapter), over 20 potential upland discharge sites throughout town have been evaluated. With few exceptions, they have been problematic because they ultimately impact our coastal estuaries.

One solution to discharge treated wastewater would be an ocean outfall. Historically, this solution has been widely used. It is still employed, for example, in Fall River, New Bedford, and Boston; and it was used in Woods Hole from 1946–1985. New outfalls were outlawed in Massachusetts coastal waters with the passage of the Ocean Sanctuaries Act, primarily to prevent poorly treated wastewater from being discharged into marine waters. That prohibition is still in place. A revision to the Act or new State legislation would be required to allow Falmouth to construct and use an outfall.

As part of reevaluating ocean outfalls, the Buzzards Bay Coalition sponsored a January 2013 meeting (Appendix 3-12) attended by 35 scientists and representatives from environmental organizations. The consensus of that meeting was that ocean outfalls should be considered as part of wastewater discharge solutions, provided that the wastewater receives tertiary treatment (e.g., total nitrogen at 3mg/L) and that careful evaluation of both the affected aquifer and receiving waters showed that an outfall would be ecologically sustainable.

In the case of Falmouth, which has a land area of 44.2 square miles and annual rain recharge between 21 and 25 inches per year, the groundwater flows toward the coastline where it discharges between 45 and 50 million gallons of freshwater per day. The Coonamessett River, for example, has an average discharge of 9 million gallons per day in March and 6 million gallons per day in June. Given these figures, a 2 million gallon per day discharge from an ocean outfall would have minimal impact on the recharge characteristics of the Sagamore Lens. In fact, average existing withdrawal of 4.4 million gallons per day of drinking water to be piped all over Town has a far greater impact on our aquifer than would discharge through an ocean outfall.

The Boston outfall, which began operation in September of 2000, provides a good example of the impact of an outfall on marine receiving waters. That outfall discharges on average 350 million gallons per day of secondary treated wastewater to Cape Cod Bay. Secondary treatment does not remove nitrogen, with the result that the Boston outfall discharges 11,000 metric tons of nitrogen per year—or 190 pounds of nitrogen for each million gallons discharged. This is the equivalent concentration of 23 mg/L nitrogen. The Boston outfall has been modeled and monitored extensively for years, both before and since operation began. To date, that monitoring has shown no significant impacts to the ecology of Cape Cod Bay. Thus, a two million gallon per day discharge of tertiary treated wastewater from Falmouth, containing 25 pounds of nitrogen per million gallons discharged, should have little effect on our receiving waters.

Further development of a scientific case for an outfall from Falmouth would require additional modeling of our aquifer by the U.S. Geological Survey and modeling of our receiving waters using 3D models developed at UMass Dartmouth and Woods Hole Oceanographic Institute (WHOI) to evaluate the ecological impacts on both systems. The science notwithstanding, the greatest hurdle to an ocean outfall in Falmouth will be the necessity to change regulations at the State level, which will require political will from Falmouth and the support of our State delegation.

3.9.2 History

Falmouth operated an ocean outfall for the village of Woods Hole from 1946-1985 that discharged chlorinated raw sewage into Great Harbor. During the 1970s as part of wastewater planning efforts, the possible use of an outfall from Nobska Point in Woods Hole extending approximately 2,000 feet into Vineyard Sound was evaluated. A series of papers were published in the Journal of the Boston Society of Civil Engineers that described these evaluations (Bumpus & Vaccaro,1971; Bumpus, Wright & Vaccaro, 1971; Meade & Vaccaro, 1971). These papers are attached in Appendix 3-10. Town Meeting at that time approved this approach but it failed at a subsequent ballot vote. Falmouth ultimately built the Blacksmith Shop Treatment Facility which discharges through infiltration beds into the West Falmouth Harbor watershed.

3.9.3 Preliminary Evaluation of a Potential Outfall at Nobska Point in Woods Hole

A preliminary evaluation of potential ocean outfall at Nobska Point in Woods Hole was completed in 2011 when the CWMP Project was evaluating wastewater collection, treatment, and recharge scenarios to address the complete High Priority Nitrogen Mitigation Area as illustrated in Figure 2-2. Though the wastewater flow has changed, this preliminary evaluation reviewed issues of an ocean outfall at Nobska Point that would still be valid for a smaller flow. The ocean outfall treatment and discharge alternative is called Scenario 1D and would have the following components:

- Wastewater collection from the Planning Area.
- Conveyance to the existing Blacksmith Shop Road WWTF and treatment to the current standards (advanced nitrogen and solids removal) followed by filtration and disinfection.
- Possible discontinuance of the current groundwater recharge at the existing WWTF site and conveyance of the total flow (from existing sewered area and needed sewered area in the Planning Area) to an additional disinfection facility in Woods Hole.
- Final disinfection and discharge through the outfall.

The proposed outfall location is illustrated on Figure 3-1 which is the same location as discussed in the Boston Society of Civil Engineers Journal articles. Costs for this scenario are summarized in Appendix 3-11 and are further discussed in Chapter 4, Section 4.4, and presented in Table 4.4. Again, these costs are dated and for a larger flow.

The costs are based on the following factors:

- Wastewater collection from the High Priority Nitrogen Mitigation Area as illustrated in Figure 2-2 with additional portions south of Route 28 to the Mashpee border and to Inner Harbor to the west.
- Wastewater treatment at the Blacksmith Shop Road WWTF to the current low-effluent nitrogen standard of 3 mg/L total nitrogen.
- Force main to be placed next to the existing wastewater force mains that extend from Woods Hole to the Blacksmith Shop Road WWTF (approximately 7.3 miles).
- Final disinfection facility and (possible) pump station.
- Three foot diameter high density polyethylene (HDPE) ocean outfall extending 2,000 feet from Nobska Point into Vineyard Sound.
- Outfall would be buried and armored as needed.
- The outfall would extend directly into the sound from Nobska Point to a tee and the outfall diffusers would be placed at right angles to the currents to maximize mixing.
- Costs are based on actual unit costs for the 1,300-foot long outfall constructed at the Seabrook WWTF in 1994. This is believed to be the last new ocean outfall (of this size) constructed in New England. Costs were adjusted based on differences in diameter, length, depth, and date of construction.

Evaluation of the non-monetary factors indicates the following findings:

- An outfall at this location with water treated to Enhanced Nitrogen Removal (ENR) standards would most likely not have an adverse environmental impact on the marine environment, but additional scientific studies would be needed to address questions and concerns of the local, regional, State, and Federal stakeholders that would need to approve it.
- An outfall at this location could have an environmental benefit because it would move the treated water (with its low nitrogen concentration of less than 3 mg/L total nitrogen) beyond the near-shore environment into a well-mixed zone of Vineyard Sound. It is noted that groundwater recharge of treated water eventually reaches the same off-shore environment; but in doing so, it moves through the near-shore environment where it causes eutrophication in the estuaries.
- By eliminating recharge of treated water within any watershed, the outfall option would reduce the amount of upper watershed sewering required to meet the TMDLs.

3.9.4 Regulatory Considerations

The Ocean Sanctuaries Act as presently constituted precludes the use of ocean outfalls in Cape Cod waters. Further consideration of this option will require changes to the Act or a Home Rule Petition. The Town would like to continue with these considerations and has begun to reach out to local stakeholders through a meeting held in January 2013 in collaboration with the Buzzards Bay Coalition (described previously) and to State officials at a meeting on May 8, 2013 held in Senator Therese Murray's office that was attended by the Senator's aide Jackie Horigan, Barry Moran from DEP, Bruce Carlisle and two staff members from Coastal Zone Management (CZM), and John Waterbury representing Falmouth.

The following list of items characterized the May 8th meeting discussion:

1. There was consensus that a solid scientific case can be made for outfalls (as defined at the Buzzards Bay Coalition meeting described earlier).
2. It was thought that it might make sense to treat ocean outfalls as part of the overall tool kit for wastewater disposal rather than having them require a special variance.
3. The case for ocean outfalls should be developed as part of the Cape Cod Commission's process to update the Section 208 area-wide water quality plan.

3.9.5 Next Steps

The following next steps are planned/recommended:

- Schedule technical meetings with representatives from DEP, CCC, Buzzards Bay Coalition, CZM, interested towns, WHOI, and others to begin to establish the criteria a municipality would need to meet in order to qualify for an outfall.
- Ask the CCC to evaluate the regional potential for outfalls at appropriate locations Cape-wide. Are there other Cape towns that cannot discharge treated effluent on land without impacting some already impaired watershed?
- Ask the CCC to model potential impacts to the various aquifers on Cape Cod from outfall discharges, such as lower groundwater elevations. Some aquifers may be more sensitive to outfall discharge than others.

- Continue to keep an outfall as an option as the Town moves forward in implementing the CWMP. Active pursuit of an outfall location would be added to the CWMP through a Notice of Project Change.

3.10 Potential Watershed Modifications for Increased Nitrogen Attenuation

Nitrogen discharged to the upper portions of watersheds travels with groundwater through fresh surface water systems (ponds, streams, wetlands, bogs, etc.). These freshwater systems provide natural nitrogen removal (also called nitrogen attenuation) before the groundwater moves into marine waters where the remaining nitrogen may contribute to water quality problems. Nitrogen recharged to the lower portions of the watershed does not flow through fresh surface waters and therefore does not benefit from such nitrogen attenuation. The separation between the upper and lower portions of the watershed is illustrated in Figures 2-1 and 2-2 for the Little, Great, Green, Bournes, Waquoit West, and Waquoit East watersheds by the horizontal line that tends to run across the top of these marine water bodies. Because some of the nitrogen discharged north of the horizontal line is removed as a function of the groundwater flow through the fresh surface water, it is believed that modifying the watershed in this area will enable a greater percentage of nitrogen to be naturally attenuated.

The nitrogen is removed due to the fundamental biochemistry that exists at the interface of the porous sandy aquifer and the freshwater system. This interface typically has an organic-rich zone populated with heterotrophic bacteria. These bacteria can use either oxygen or nitrate as their electron donor (oxygen) source for respiration as part of their metabolism. When they use nitrate for respiration, they excrete nitrogen gas (N_2) that goes off to the environment. This organic-rich zone typically has low dissolved oxygen (due to the bacteria consuming it) and the bacteria will then consume the nitrate from groundwater as it flows through the interface. Some aquifer/freshwater system interfaces have better organic-rich conditions than others; therefore, some freshwater systems are better at nitrogen attenuation than others. There are other denitrification mechanisms at work in these freshwater systems; but this is the major one.

3.10.1 Findings From the November 2007 Alternatives Screening Analysis Report

The November 2007 Alternatives Screening Analysis Report identified that significant nitrogen attenuation (40- to 60-percent) has been documented by SMAST as part of the MEP evaluation for various fresh water bodies. This report also developed the following three alternatives for more evaluation:

1. Freshwater pond construction and impoundments in the cranberry bog systems.
2. Constructed wetlands in the cranberry bogs.
3. Constructed wetland/reactor with Nitrex™ media.

These alternatives focused on the Coonamessett River area because it is a Town-owned area but they could be applied to the Backus Brook bog system, the Bournes Brook bog system, or other low-lying wetland areas after further study and implementation in the Coonamessett. These alternatives are described in detail in Appendix 3-14.

3.10.2 Summary of Considerations for the Watershed Modification Alternatives

The three alternatives identified for the Coonamessett River watershed hold promise for relatively cost-effective nitrogen mitigation. The “Constructed Wetlands” and the “Constructed Wetland/Reactor with Nitrex™ Media” alternatives both use pump-and-treat technologies that are believed to be unacceptable to the environmental regulators and would have long-term operation responsibilities for the Town that would be costly and problematic. The "Freshwater Ponds Impoundments" alternative is a more passive/natural concept that will be more acceptable to the regulators and it has minimal operation requirements and costs. This is the concept/alternative that should be pursued.

3.10.3 Discussions with the Coonamessett River Restoration Committee

The Coonamessett River Restoration Committee was contacted to consider this water-quality improvement goal and the possible implementation of freshwater ponds/impoundments as part of their restoration efforts. Also, Dr. D. Michael Ball of ENSR/AECOM (the environmental consultant engaged by the Coonamessett River Restoration Committee) was contacted in January 2008. He indicated that ENSR/AECOM had recently completed a Draft Restoration Concept Report (December 2007). A conceptual river modification plan from that report is attached in Appendix 3-14. The plan illustrates the addition of flow deflectors and rocks to the stream to improve the fish habitat, and the re-vegetation of the bog to recreate more of a natural wetland. The main goal of this restoration plan was to restore the wetland and fish run.

A meeting was held with Greg Pinto, Chairman of the Coonamessett River Restoration Committee; George Hampson of the Town's Nutrient Management Committee; and Jerry Potamis, Falmouth Wastewater Superintendent on April 15, 2008 to review the findings of these watershed-modification evaluations and to learn if the goals of the watershed modification to improve water quality could be incorporated into the Committee's goals of wetland restoration to restore fisheries habitat. After discussions of how freshwater ponds and impoundments could be utilized to meet these goals, the group agreed to incorporate the water-quality goal with the Committee's goal to restore fisheries.

It was understood that large ponds could increase the temperature of the water which could defeat the Committee's main goal of trout restoration to the stream. It was believed that this potential conflict of goals could be addressed by keeping the ponds/impoundments small in size, located to the sides of the bog systems, and designed to encourage shading through plantings.

The Coonamessett River Restoration Committee has completed its work and has been disbanded.

3.10.4 Considerations on Modifications in the Backus Brook Bog System, Bournes Brook Bog System, and Low Lying Areas North of Eel Pond and Childs River

The Backus Brook Bog system is north of Green Pond, extends from Route 28 to Carriage Shop Road, and is actively farmed. This bog system has a tail-water pond (Mill Pond) at its southern end and provides significant nitrogen attenuation (67-percent for the Backus Brook system verses 51-percent for the Coonamessett River System per MEP, April 2005). This is the type of pond/impoundment that is recommended for bog systems to promote nitrogen attenuation. The nitrogen attenuation through this pond is believed to be a major factor in the lower wastewater nitrogen removal percentage that is needed for this watershed verses the other watersheds in the Planning Area. No modifications to the Backus River Watershed are recommended at this time. It is possible that on-going research and water-quality monitoring at the pond or at the watershed will indicate benefits of modifying these systems for nitrogen attenuation. At that time (and with the possible benefit of positive findings with the Coonamessett Bog restoration work) possible watershed modifications can be considered for Backus Brook and Mill Pond.

The Bournes Brook Bog system (also called the Hammond Bog) is north of Bournes Pond, extends from Route 28 to the Falmouth Country Club site, and is actively farmed. The cranberry farmers have been working with the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) on a resource assessment for the bog and the following items are being considered for water quality and management improvements:

- Route 28 culvert modification.
- Modification of the lower bog cell to a natural wetland or to tail-water pond.

Final determination of these items has not been made. As with the Backus Brook bog system, it is possible that on-going research and water quality monitoring at the watershed will indicate benefits of further modifying this system for nitrogen attenuation. At that time (and with the possible benefit of positive findings with the Coonamessett River restoration work) possible watershed modifications can be considered for the Bournes Brook bog system.

There are wetland areas north of Eel Pond and Childs River that may be providing significant nitrogen attenuation. These areas are in the Waquoit West watershed that is still being evaluated by the MEP for nitrogen limits.

3.10.5 Additional Applications of Vegetative Treatment

The WQMC will continue to consider new ways in which the use of vegetative swales and related technologies—either ‘high tech’ or ‘low tech’—could effectively and economically remove nitrogen. Promising technologies will be incorporated into the CWMP through Adaptive Management and a Notice of Project Change as needed.

3.11 Baseline Monitoring

An over-arching concern and key aspect for all the demonstration projects in this chapter as well as the sewering project described in Chapter 4 is Baseline Monitoring: How will the Town and the Regulators know what environmental improvements have occurred as a result of particular actions taken to intercept nitrogen currently flowing into a given water body.

The Town’s approach is proposed as follows:

1. Water quality data collected by SMAST for the MEP reports forms the baseline picture on which the TMDLs are set. These data were gathered during the first half of the 2000-2010 decade.
2. Water quality data collected by the Pond Watchers annually since the MEP reports (roughly 2006 to present) has been accumulated by SMAST but not analysed or reported.
3. The WQMC has contracted with SMAST to have the data for Little, Great, Green, and Bourne’s Ponds, Eel River, and West Falmouth analysed and reported.
4. DEP has stated that the monitoring plan to establish a causal link between a demonstration project and water-quality improvements must include one year of baseline data prior to project installation and at least three years of active monitoring of the project.
5. As demonstration projects move forward, estuary by estuary, a monitoring plan specific for that project will be developed with input from the appropriate regulating agencies. As examples:
    a. The monitoring plan for Little Pond Aquaculture Project was developed with input from the Falmouth Conservation Commission, the Division of Marine Fisheries, SMAST, and others; and then formalized in an Order of Conditions.

b. The Monitoring Plan for Bourne's Pond inlet will be developed during the design and permitting process, involving all agencies that have jurisdiction, and following the MEPA/DRI process.
c. Whichever estuary is selected for installation of a Permeable Reactive Barrier will need a monitoring plan for the groundwater prior to installation, both upstream and downstream of the proposed location, as well as near-shore monitoring of the coastline of the particular estuary affected. The Falmouth Conservation Commission is likely to play an important part in developing the plan.

6. It is likely that each estuary will ultimately end up with its own particular baseline monitoring plan, followed by on-going monitoring, tailored to the nutrient management technologies planned for that estuary.
7. Any demonstration project that enters the MEPA process will need to prepare a monitoring plan as part of that process.
8. To establish the nitrogen removal credit of eco-toilets, the Eco-Toilet Demonstration Project includes a year-long testing program administered through Barnstable County Department of Health and Environment. Once an eco-toilet has been installed, thus diverting human urine and feces, this monitoring program tests the nitrogen and phosphorus content of a household's greywater on a monthly basis for 12 months.
9. On-going monitoring of the demonstration projects will be dictated by the nature of the project, regulatory requirements, and the need for more or less data depending on the consistency of the monitoring data as it is collected.
10. In the case of sewering a peninsula, the expected reduction in nitrogen should be evident first in the groundwater under the peninsula before it reaches the estuary. Some consideration should be given to sampling groundwater in Maravista and/or Falmouth Heights before sewering and then afterwards.

Ultimately, long-term monitoring of each estuary will be needed to prove that the Town is continuing to meet the TMDL's. Consideration should be given to simplifying the monitoring protocol so that the necessary 'indicator' data are collected, without spending time or money on secondary parameters.