Inter-municipal Watershed Planning and TMDL Implementation to Restore Embayment Water Quality on Cape Cod:

Three Case Studies of Towns Sharing Coastal Watersheds

November 2008

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University of Massachusetts Dartmouth
School of Marine Science and Technology

Disclaimer

This project, “Protecting Coastal Waters through Watershed-Wide Permitting and Nutrient Trading in Three Massachusetts Estuaries,” has been funded through a Cooperative Agreement (CP98184301) utilizing Federal Funds from the Environmental Protection Agency to the Massachusetts Department of Environmental Protection. The views expressed do not necessarily reflect those of the EPA or of MassDEP. Mention of trade names, products, or services does not convey, and should not be interpreted as conveying, official EPA or MassDEP approval, endorsement, or recommendation.

Front Cover: A view of Shoestring Bay, Mashpee, Massachusetts
Photograph by George Zoto

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Preface

This report presents the findings and recommendations from three Pilot Projects on Cape Cod; each addressing the watershed nitrogen load conditions affecting water quality impairment for three estuaries: Popponesset Bay (Mashpee, Barnstable, and Sandwich, MA); Three Bays (Barnstable, Sandwich, and Mashpee, MA), and Pleasant Bay (Chatham, Orleans, Brewster, and Harwich, MA). The outcome of these case studies, including what was learned, and the actions taken and/or recommended for follow-up, represent several years of dialogue among the towns sharing land use jurisdiction of the affected watersheds.

Each estuary had been designated by the Commonwealth as a nitrogen impaired estuary - in violation of the state water quality numerical standards and its designated uses (recreational fishing, swimming and boating and as habitat for sustaining eelgrass meadows as a breeding and nursery ground for important commercial marine fisheries and shellfish).

Past wastewater planning elsewhere in the US and in New England are typically focused on end of pipe point (NPDES) discharges to receiving surface waters. These case studies on Cape Cod address the fact that wastewater impacts to coastal embayments are not from typical NPDES discharges but from nonpoint source discharges to the ground from septic systems, stormwater runoff, large and small wastewater treatment plants, and use of fertilizers by the towns sharing the watershed. These case studies utilized a holistic, scientific approach by evaluating all nitrogen sources in the watershed for use in integrating a broad range of infrastructure and management solutions into existing state permitting programs.

For an electronic version, please visit: < http://www.mass.gov/dep/water/resources/coastalr.htm>.
The digital copy includes numerous hyperlinks to websites.

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MassDEP does not necessarily agree with all the recommendations expressed in this document by persons or groups that have participated in the project. Nor is MassDEP committing at this time to implement any of the recommendations made by others.

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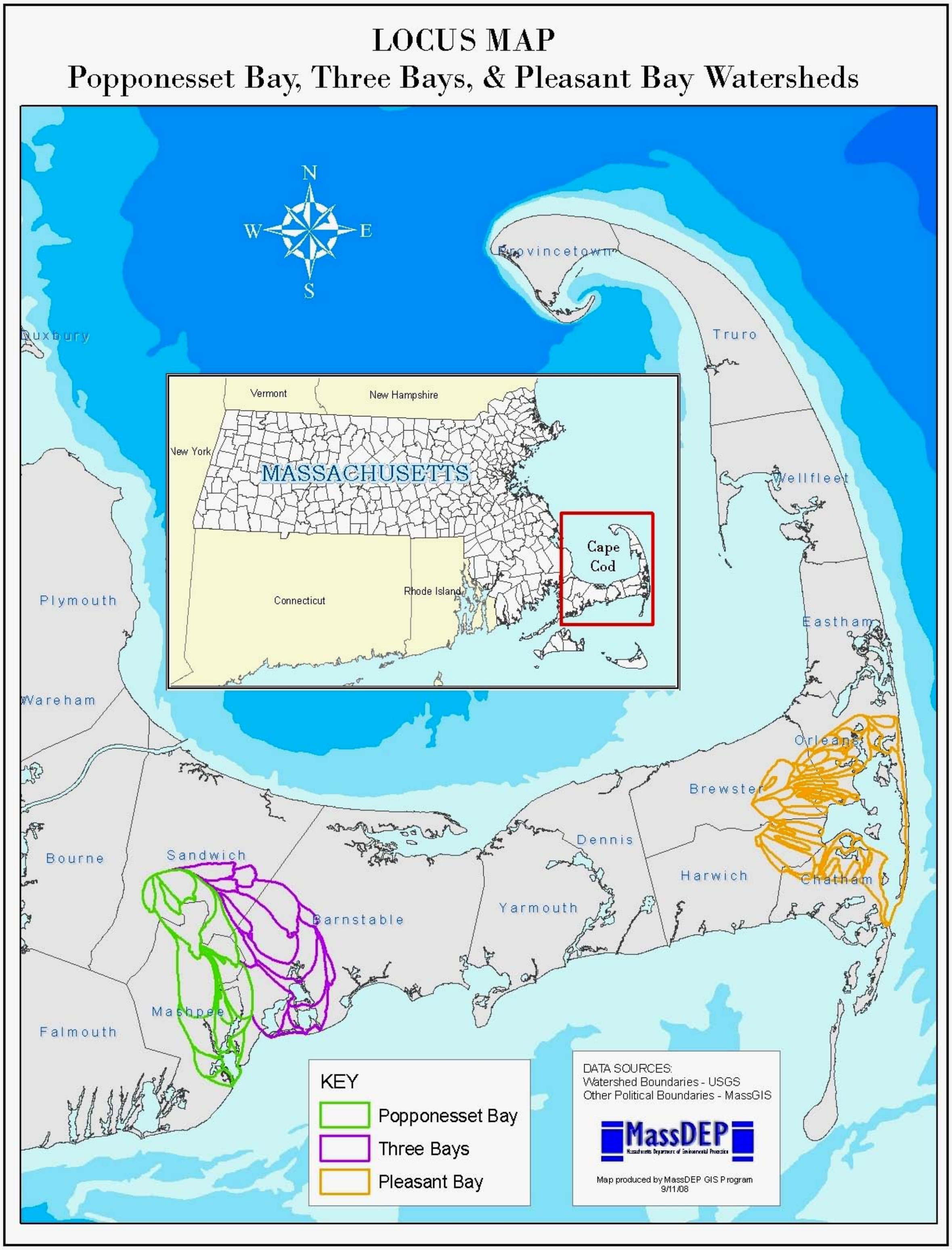

LOCUS MAP
Popponesset Bay, Three Bays, & Pleasant Bay Watersheds
N
W
E
S
Provincetown
Truro
Wellfleet
Eastham
Orleans
Brewster
Chatham
Harwich
Dennis
Yarmouth
Barnstable
Sandwich
Mashpee
Bourne
Falmouth
Wareham
Plymouth
Duxbury
Vermont
New Hampshire
New York
MASSACHUSETTS
Cape Cod
Connecticut
Rhode Island
KEY
Popponesset Bay
Three Bays
Pleasant Bay
DATA SOURCES:
Watershed Boundaries - USGS
Other Political Boundaries - MassGIS
MassDEP
Map produced by MassDEP GIS Program
9/11/08

Chapter 1: Introduction

The significance of protecting estuaries is clear. Estuaries, as the boundary between land and sea, are also the mixing zones where the freshwaters of the land and the salt waters of the ocean meet. This mixing/transition zone, or ecotone, promotes the environmental conditions that make estuaries among the earth's richest and most productive ecosystems. Healthy, biologically diverse estuarine ecosystems are able to sustain habitat, spawning grounds and nursery conditions to at least two-thirds of the Nation's commercial fisheries, while providing for the recreational and aesthetic enjoyment of the public.

Ironically, as the winter and summer coastal population grows, the estuaries that once attracted these people as visitors are now under increased assault, as they are now attracted to live there year-round. According to the National Oceanic and Atmospheric Administration (NOAA) "the coastal zone has become the most developed in the nation. This narrow fringe–comprising 17% of the contiguous U.S. land area is home to more than 53% of the nation's population. Furthermore, the coastal population is increasing by 3,600 people per day, giving a projected total increase of 27 million people between now and 2015" (see: http://www.epa.gov/owow/estuaries/about1.htm).

As a result of these growth pressures, ambient water quality at estuarine locations has been increasingly under assault and at risk from human dominated land use changes within the coastal watershed. The water quality impacts were primarily from:

- Expansion of urbanization and wastewater collection and disposal systems discharges that collectively contribute 75-85% of the nitrogen load to southeastern Massachusetts' coastal estuaries;
- Loss of open space and the proliferation of impervious pavement (roof tops, sidewalks, parking lots, and roadways) that contributed to the loss of groundwater recharge from rainfall events and the increase in stormwater runoff discharges to coastal waters;
- Expansion of stormwater collection and disposal systems that discharge untreated to inland and coastal waters and the excess nutrient contamination from its many sources;
- Higher volumes of urban nonpoint runoff;
- Noticeable increases in nitrate levels in drinking water

The accompanying decline in water quality, primarily from nitrogen discharges from residential on-site septic disposal systems, residential lawn fertilizer use, and stormwater discharges has detrimentally affected the biological richness and productivity of these ecosystems that once supported spawning grounds and nursery for a vast array of shellfish and commercially important fisheries. This decline has also affected tourism, property values, and the economy of affected coastal areas. (see: http://oceanservice.noaa.gov/education/pd/estuaries/welcome.html).

1.1 Nitrogen Pollution

It is well established that nitrogen is essential to living organisms and its availability is critical to functioning estuarine ecosystems. However, unlike freshwater ecosystems where phosphate is the limiting nutrient, marine ecosystems are limited by nitrogen. This means that freshwater and marine ecosystems have all the nutrients needed for growth – except for phosphate and nitrogen. When either nitrogen or phosphate concentrations exceed natural background levels, the affected marine or freshwater ecosystems undergo eutrophication (http://www.town.barnstable.ma.us/PublicWorks/nutrients1.pdf), with an explosive growth of undesired phytoplankton (blooms) and algal mats that overwhelm and degrade the ecological functioning of these inland and coastal waters. However, it must also be understood that eutrophication is a natural process that occurs over a long period while cultural eutrophication, the dynamic affecting this and other coastal embayments, is a human influenced acceleration of this natural process.

The collapse of the affected coastal ecosystems soon follows. During the day the algal blooms supersaturate the water column with oxygen and at night, this oxygen is depleted by biological respiration. Finally, when the algal bloom undergoes decay and microbial decomposition most of the dissolved oxygen in the water column is consumed leaving very little for the affected ecosystem to sustain itself.

Figure 1.2 A view of Shoestring Bay from the Santuit River with algal mats throughout much of the surface waters of the Bay (Photo by Ed Baker)

Eutrophication also results in the buildup of carbon rich bottom sediments resulting from the fallout of this algal and plant biomass from the water column. This bottom settlement buildup can have long-term changes in benthic habitat, animal populations, and community structure – collectively with the potential to affect biogeochemical cycles, living resources, and biodiversity.

It is important to understand the connection between nitrogen pollution and the decline of eelgrass beds. When the water column is overwhelmed by an algal bloom, it is no longer transparent to sunlight penetration. The shading that results from these algal blooms and the attached epiphytic algae is such that the eelgrass beds are no longer receiving sufficient sunlight to fuel their photosynthetic needs on the seafloor (Kemp et al., 1983). The subsequent loss of these eelgrass beds soon has a domino effect on the ecosystem it had sustained, with the loss of its dependent plant and animal community; including habitat, breeding ground, and nursery to its dependent commercial fisheries and shellfish.

Increases in estuarine nitrogen levels have also affected the health and functioning of the saltwater marshes that had been dominated by *Spartina alternafolia* (seagrass). The introduction of nitrogen to these ecosystems will over time result in a community dominated by *Phragmites australis*. Phragmites thrives in nitrogen enriched estuaries and easily out competes *Spartina* for both sunlight and nutrients as it spreads its dense growth of underground stems (rhizomes). Collectively, this dense growth pattern and slow rate of winter decomposition of its rhizomes and leaves, results in a degraded habitat that no longer sustains preexisting wetlands function when these thick stands become elevated and fill in the previous open waters.

Nitrogen enrichment from groundwater and stormwater can have a profound affect on the functioning of estuarine ecosystems. When present at levels that exceed its capacity to function, it will have a damaging and catastrophic effect on its dependent plant and animal communities. This report focuses on three tidally restricted coastal embayment systems on Cape Cod that have been affected by elevated nitrogen concentrations resulting from increases in housing, population densities, and septic system discharges.

1.2 Case Studies on Watershed-Based Permitting: Massachusetts Roadmap for Regulatory Change

The need for these case studies is clear. The discharge of untreated, nonpoint source discharges of wastewater continues unchecked from population growth and land use development from many of the communities on the south shore of Massachusetts. Seasonal homes have become year-round, undeveloped land has continued to be lost with the development of year-round residences, road networks, businesses and municipal buildings. The loss of open space with each new development has collectively contributed to the decline in water quality; primarily from the discharges of nitrogen from septic systems, lawn fertilizers, and stormwater runoff. This decline in water quality is especially noticeable in the small upper sub-embayments where septic system load discharges have increased steadily with land development in a small sub-embayment system that has a limited capacity to exchange its nutrient laden waters with clean seawater during each tidal cycle.

At some point, the untreated wastewater discharges will need to be managed to reduce the impacts to these nitrogen impaired embayments. The degradation of water quality to these embayments has frequently been from more than one community sharing the affected coastal watershed resource. The driving force for this study has been to learn how towns sharing a coastal watershed resource would address their load reductions. Would they do it alone or in collaboration? It is clear that the resolution of these questions will not be easy as the priorities may not be the same for all towns sharing the watershed to an impaired embayment. MassDEP faces the difficult challenge of promoting watershed wide, inter-municipal planning and coordination to achieve these reductions while integrating the management of town-specific and watershed-wide, inter-municipal CWMPs into the existing NPDES and groundwater discharge permitting framework.

Unlike past wastewater facilities planning that historically focused on the mitigation of NPDES point discharges within a community or within one of its villages, a watershed-wide, inter-municipal approach was being pursued to promote shared planning and responsibility for reducing nonpoint source loads of nitrogen to a nitrogen sensitive estuary. The goal of this project was to identify the issues that would define each study and how they would be resolved.

It was for this reason, with funding provided by an US Environmental Protection Agency (EPA) Water Quality Cooperative Agreement that this project was undertaken to address the pathways the towns and the state would take when two or more municipalities share responsibility for restoring water quality to a nitrogen impaired embayment. Also of interest was how the towns, county, and the MassDEP would resolve any zoning, regulatory or permitting issues that address the watershed-wide nitrogen load reductions. Other issues addressed were: (1) inter-municipal strategies towns could engage in for the restoration of water quality from the land use impacts they collectively share responsibility for its restoration and (2) identifying barriers in local zoning, regulations, state statutes, regulation or policies and recommending ways these barriers could be overcome.

In sum, the major nutrient management issues of concern pertained to inter-municipal collaboration and allocation of responsibility, including actions taken and recommendations for the future. This project also focused on identifying barriers in local zoning, regulations, state statutes, regulations and polices and recommending how they could be overcome.

1.2.1 Selection of Coastal Watersheds

The coastal watersheds were selected using the following criteria: a) at least two or more communities sharing jurisdiction of a coastal watershed; and b) a signed agreement with a commitment to attend and participate at regular scheduled meetings. Case study participants, referred to as the Pilot Project Team, would use the findings of the MEP Technical Report and the EPA approved TMDL to define the watershed nitrogen loads and load reductions needed to restore eelgrass or the shellfish benthic habitat - the ultimate compliance criterion for deciding if water quality restoration had been achieved; even if the nitrogen water quality standard had not been met.

In addition, the teams were also tasked to identify and develop creative decision-making, nutrient management solutions. Ultimately, this information would be shared with other coastal communities. The three coastal watersheds from Cape Cod and the towns sharing land use jurisdiction for these case studies were:

- Popponesset Bay – Towns of Mashpee, Sandwich and Barnstable
- Three Bays – Towns of Barnstable and Sandwich
- Pleasant Bay – Towns of Chatham, Harwich, Orleans, and Brewster

Each of the affected embayments has been designated by the Commonwealth of Massachusetts as nitrogen impaired - a violation of the state's surface water quality standards for its designated uses (recreational fishing, swimming, boating and a habitat for sustaining eelgrass meadows as a breeding and nursery ground for important marine fisheries and shellfish).

This project was initiated with the goal of promoting watershed-based, inter-municipal planning and coordination. However, this would need to overcome the Commonwealth's history of strong local home rule and municipal authority. Few examples exist in the Commonwealth for guiding inter-municipal wastewater management planning and implementation. It was the hope that these case studies would define some of the issues of concern and how they would be resolved when two or more towns share responsibility for reducing nitrogen throughout a watershed to a nitrogen-impaired embayment. The lessons learned and the recommendations presented in these case studies are, at best, a first step to a lengthy, deliberative planning and implementation process that encompass the steps that have been defined in Figure 1.3.

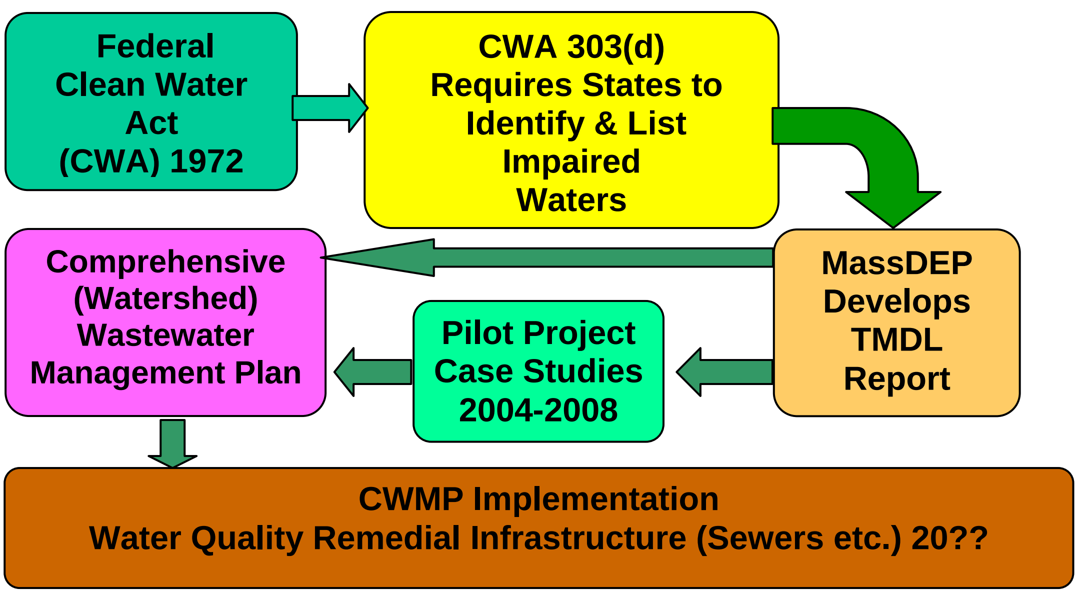


Figure 1.3 Diagram Defining the Pilot Project Case Studies Role in the Implementation of a TMDL

1.2.2 Watershed and Embayment Characteristics

The estuaries and ground-watersheds that defined each of the three case studies are dissimilar in land use, population/housing density, proximity of discharges to the coast, the role of natural attenuation to denitrify nitrogen loads, the number of towns sharing the watershed, and its tidal flushing cycle (the embayment inlet's capacity to exchange its waters within a tidal cycle). Any one or more of these characteristics define the uniqueness of these embayment systems and the mitigations required for reducing nitrogen loads.

As a result, an understanding of these watershed/subembayment differences is critical to the management decisions affecting the selection of any nitrogen load reduction scenario that achieves the threshold concentration at a sentinel station. Further discussion on Cape Cod's embayments can be found at: http://www.capecodgroundwater.org/groundwateredpage/embayment.pdf

1.2.3 Pilot Study Team Recruitment

Recruitment of communities for the project required:

- A strong lead town – a commitment to participate in advance, prior to any particular outcomes.
- Each town designate a primary contact or "point person" who would solicit input from a broad range of municipal and nongovernmental citizen groups. However, the work of the Pilot Team required a commitment to attend meetings and contribute to the ongoing dialogue.
- Participation in and support of an inter-municipal team through informal meetings, problem solving, and the shared responsibility to reduce nitrogen loads either jointly or alone through the formal CWMP planning process.
- Interest in promoting inter-municipal watershed-wide cooperative planning.

MassDEP also enticed participation by covering the cost of the Linked Model runs to evaluate the effect of proposed watershed nitrogen reductions by the Pilot Study Team on the threshold concentration at the sentinel station(s).

MassDEP's Case Study Project Manager, as team leader, was responsible for team recruitment; the scheduling/coordination of team meetings; educating stakeholders about the MEP process and the applicable state and federal regulatory rules; presenting/discussing wastewater treatment options; and defining/resolving issues of concern for follow-up by local, regional, and state policy makers.

1.2.4 Pilot Project Team Guiding Principles

Participating Pilot communities understood that the lessons learned would guide them with the planning and implementation of their Comprehensive Wastewater Management Plans. Likewise, MassDEP would evaluate how its policies and regulations could be enhanced to promote a state regulatory framework that facilitates local and regional watershed efforts that are consistent with the restoration of estuarine water quality.

The following facts guided case study meeting discussions:

- Wastewater discharges to the watershed are the dominant sources of nitrogen pollution affecting estuarine water quality;
- Most estuaries require nitrogen load removals of nearly 75% to achieve water quality restoration at their designated embayment sentinel station;
- Identify the most cost-effective and environmentally appropriate restoration scenario
- Sewering is key, but towns must first evaluate the many technical and institutional options;

- Solutions will cost many millions of dollars and take many years;
- Towns sharing a coastal watershed should work together to define optimal solutions that are:
    - Watershed-wide
    - Environmentally-sound
    - Cost effective

Equally important, the towns understood the importance of examining all nitrogen reduction options, including:

- Land use alternatives that reduce the need for sewering,
- Evaluating creative, nontraditional ways to solve the nitrogen problem beyond the typical wastewater treatment focus of Comprehensive Wastewater Management Planning,
- Aquaculture that provides habitat, water quality, and community benefits.

Team meetings also discussed wastewater infrastructure, management and regulatory practices for reducing nitrogen loading from existing and proposed land uses at build-out, including the following:

- Better wastewater treatment: sewers, small systems, onsite septic disposal
- Stormwater runoff and fertilizer use controls
- Embayment flushing improvements
- Natural attenuation
- Water reuse
- Wastewater management districts
- Watershed-wide cooperative arrangements
- Land use controls
- Nitrogen offsets and trading

1.2.5 Team Meetings

The Pilot Project Team consisted of town officials and representatives of environmental organizations from the participating towns and environmental organizations sharing the watershed, with support from the Cape Cod Commission, MassDEP, and SMAST. Team meetings varied but on average were held monthly.

Each Case Study involved the following:

- An in-depth understanding of the Technical Report and use of the Linked Model;
- A review of the nitrogen reduction scenario described in the MEP Technical Report (Chapter VIII.3);
- Team proposals for three model runs by SMAST, based on nitrogen reduction options to determine if the threshold concentration at the sentinel station is achieved; and
- Discussion of local and state management and regulatory issues.

Case study meetings identified a number of issues for improving the CWMP and TMDL implementation process and the recommendations for adoption of a broad range of infrastructure and management practices by local, county, and state polices and regulations. The lessons learned from the Pilot Projects are combined and presented in detail in Chapter 6, under the heading “Recommendations”.

1.3 The Massachusetts Estuaries Project (MEP)

1.3.1 MEP History

In 2000, the Massachusetts Executive Office of Environmental Affairs and the University of Massachusetts signed a cooperative agreement to collaborate on environmental projects. The idea was to give the Commonwealth access to the talent pool at UMass campuses, while giving students the opportunity for hands-on study. This agreement led to the launching of the Massachusetts Estuaries Project (MEP) in 2002 (see: http://www.oceanscience.net/estuaries/about.htm) with partial funding provided by the Massachusetts Legislature to address the pollution from excess nitrogen loading in 89 estuaries in southeastern Massachusetts (http://www.oceanscience.net/estuaries/progress.htm). As a multiyear $13 million dollar project, financed by federal, state, municipal, and private funds, this project involved the collaboration of the University of Massachusetts at Dartmouth's School Marine Science and Technology (SMAST), the Massachusetts Department of Environmental Protection (MassDEP), the Executive Office of Energy and Environmental Affairs (EOEEA), the MEP coastal communities in southeastern Massachusetts, the Cape Cod Commission, the US Environmental Protection Agency (EPA), Applied Coastal Research and Engineering, and the U.S. Geological Survey.

The estuaries and embayments of southeastern Massachusetts extend from the Town of Duxbury to the City of Fall River, encompassing all of Cape Cod and the Islands, Buzzards Bay and Mt. Hope Bay. Many of these estuaries are at risk of, or are experiencing degraded water quality and habitat loss from watershed-based nitrogen load impacts. With local communities dependent on the preservation of water quality for sustaining their fishing, shellfishing, and tourism industries, the degradation of these estuarine water resources has serious economic consequences; including reductions in property values, local commerce, and tax revenues. Given the synergy among these interests, embayment protection and restoration is of paramount importance to the Commonwealth and its coastal communities.

1.3.2 MEP Linked Watershed Embayment Model

The MEP uses a model developed at the University of Massachusetts Dartmouth School of Marine Science and Technology (SMAST). Input parameters required for modeling include physical, chemical and biological data. Collectively these model inputs calculate the capacity of an embayment to assimilate nitrogen and run predictive scenarios for use in planning water quality restoration through nitrogen reductions throughout an impacted subwatershed.

The complexity of the nitrogen flows to the estuary from subwatershed discharges (septic systems, fertilizer use, stormwater runoff, atmospheric deposition, and benthic flux) and its interaction with the environment (natural attenuation, tidal flushing, and benthic regeneration) is reflected in the results generated by the MEP Linked Watershed Embayment Model (Appendix B). At best, the model is a quantitative estimate of an embayment's: (1) N sensitivity, (2) N threshold loading levels (TMDL) and (3) response to changes in nitrogen loading. The Linked Model approach, after it is fully field validated, and calibrated accounts for all sources of nitrogen loads, the reduction by natural attenuation, nutrient recycling, and the variations in an embayment's water quality resulting from a bay's hydrodynamics (current, tidal range, bathymetry) (Figure I-2 of each Technical Report). In short, the Linked Model approach integrates the water quality monitoring results from the field with the data collected on its hydrodynamics, as listed below:

- Water Quality Monitoring - multi-year, 3-year minimum, embayment nutrient sampling
- Hydrodynamics
  - Embayment bathymetry (depth contours throughout the embayment)
  - Site-specific tidal record (timing and height of tides)
  - Water velocity records (in complex systems only)

  - Hydrodynamic model
  - Watershed N Loading
  - Watershed delineation
  - Stream flow and N load
  - Land-use analysis (GIS)
  - Watershed N model
- Embayment Threshold Development - Synthesis
  - Linked Watershed-Embayment N Model
  - Salinity surveys (for Linked Model validation)
  - Rate of N recycling within embayment
  - Dissolved oxygen record
  - Macrophyte (eelgrass and other plants living on the bottom of an embayment))
  - Infaunal survey (benthic/bottom dwelling animals) in complex systems

1.3.3 Sentinel Stations

Prior to initiating the water quality studies, the MEP team first identified for each impaired embayment representative sampling location(s) within the system and at its headwater sub-embayments. Following three years of water quality sampling, testing, and data collection, the MEP technical team was able to analyze this data for use in identifying sentinel station(s) that are representative of current water quality throughout a nitrogen-impaired embayment. Usually, the sentinel station is the furthest from the ocean inlet with the best potential for demonstrating that water quality and habitat throughout the embayment system to its headwaters has been restored when the nitrogen threshold concentration has been met at that location. Some systems, such as Pleasant Bay, have more than one impaired embayment and as such have several sentinel stations. Once the model has been calibrated and validated with this input data, it is possible to run the model to determine if one or more proposed subwatershed-load reductions for each nitrogen impaired embayment has the potential to restore water quality at its sentinel station. This information is then used by the towns for CWMP planning and implementation.

The target concentration of total nitrogen (TN) that is restorative of water quality and eelgrass habitat at any sentinel station is site specific and dependent on the restoration of eelgrass and/or benthic animal habitat. Since Popponesset Bay was without an established eelgrass bed, the establishment of a threshold concentration required site visits to similar habitats where eelgrass exists such as those at Stage Harbor (Chatham) and Waquoit Bay (Mashpee), near the inlet (measured TN of 0.39 mg TN/liter, tidally corrected <0.38 mg N/Liter) and a similar finding in West Falmouth Harbor. However, with this said, the use of a threshold concentration for all embayments in setting the TMDL is not the ultimate test for compliance with water quality standards; it will ultimately be the restoration of eelgrass and/or benthic habitat even if water quality exceeds the 0.38 mg/L TN standard; as it was determined for Pleasant Bay's embayments when TN was affected by dissolved organic carbon (see pages 138-140 of this report). The secondary threshold standard for restoring benthic infaunal habitat was set between 0.400 and 0.500 mg/L TN.

Determining the acceptable maximum level of TN, without causing unacceptable harm to habitat is a major part of threshold development. Prior to conducting model runs, SMAST selected appropriate nutrient-related environmental indicators and tested the qualitative and quantitative relationship between those indicators (eelgrass and benthic infaunal species) and the TN concentrations. The Linked Model was then applied to determine the site-specific threshold TN concentrations of each sampling location by using the specific physical, chemical and biological characteristics of each embayment, corrected for tidally driven variation in TN concentration at each site within an embayment. As a result, the calibrated and validated water quality model for a chosen sentinel station reflects the average TN concentration in the upper embayment that is the most representative of the conditions within the estuary and its sub-embayments.

When the model is validated to existing watershed and estuarine conditions, the MEP Linked Model provides MEP communities with a powerful planning and management tool for use in identifying the best sewering and disposal options, by running additional model simulations using alternative scenarios (various nitrogen loading schemes, enhanced flushing possibilities, and/or enhanced natural attenuation) for deciding what option provides the best nitrogen reduction and cost for restoring water quality as part of wastewater management planning; a process that ultimately leads to a comprehensive wastewater management plan (CWMP) with a preferred solution. The CWMP is then submitted to the state for its review and approval as part of the TMDL planning and implementation process (Figure 1.4)

1.3.4 MEP Technical Reports

The MEP Technical Report is the final product from SMAST that defines the nitrogen discharge load of the coastal watershed and its subwatersheds, the embayment's hydrology, and proposes a hypothetical nitrogen reduction scenario for restoring water quality to the threshold concentration at the sentinel station. Town officials should not assume that the nitrogen load reduction scenario proposed in the MEP Technical Report is the preferred option. They should decide on a load reduction strategy that works best for their community prior to making a final decision. These include such factors as population/housing densities, availability of land for construction of proposed wastewater treatment/disposal facilities, proximity to existing satellite treatment plants, and the costs and benefits. Identifying the scenario that makes environmental and cost-benefit sense could require several additional model simulations before the preferred option is identified for the CWMP the town is preparing.

1.3.5 MEP Estuarine Restoration Process

As outlined in Figure 1.4 and further defined in Chapter 8, the MEP represents a long-term wastewater planning and implementation process, with a repeating cycle that relies heavily on five action steps:

Step 1: Gather Watershed Data

This involves watershed delineation, land use data, embayment hydrology, water quality, and habitat sampling for a three–year period with oversight and support by the University of Massachusetts at Dartmouth's School of Marine Science and Technology (SMAST) and Applied Coastal Research and Engineering, Inc (ACRE). In addition, SMAST coordinated its efforts with the Cape Cod Commission to generate watershed-based nitrogen loads.

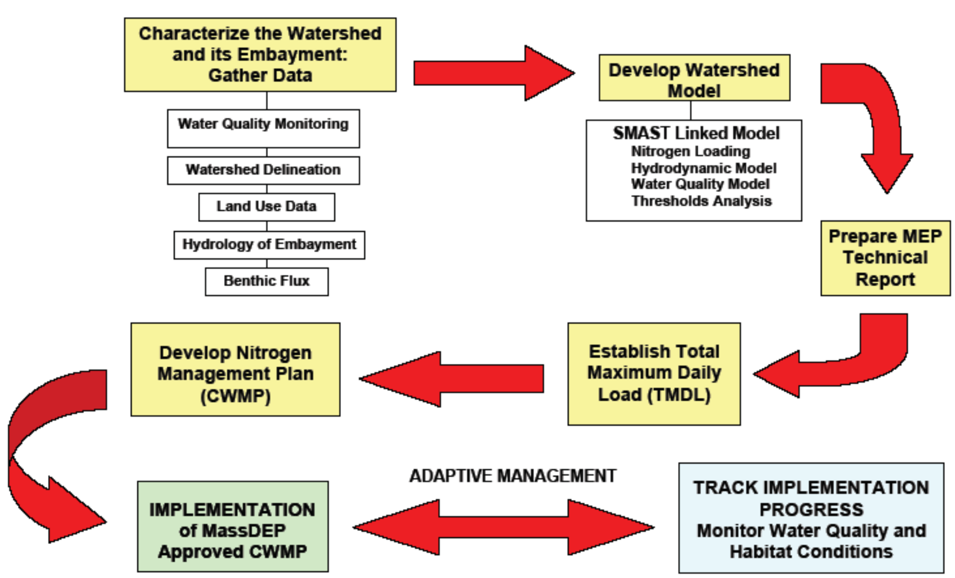


Figure 1.4: The Massachusetts Estuary Project Restoration Process

Step 2: Develop the Watershed Model

The core of the Massachusetts Estuaries Project analytical method is the Linked Watershed-Embayment Management Modeling Approach. It fully links watershed inputs with embayment circulation and N characteristics, and is characterized as follows:

- requires site specific measurements within the watershed and each sub-embayment;
- uses realistic best-estimates of N loads from each land-use (as opposed to loads with built-in safety factors such as Title 5 design loads);
- spatially distributes the watershed N loading to the embayment;
- accounts for N attenuation during transport to the embayment;
- includes a 2D or 3D embayment circulation model depending on embayment structure;
- accounts for basin structure, tidal variations, and dispersion within the embayment;
- includes N regenerated within the embayment;
- is validated by both independent hydrodynamic, N concentration, and ecological data;
- is calibrated and validated with field data prior to generation of additional scenarios.

The Linked Model, when properly calibrated and validated for a given embayment, becomes a nitrogen management planning tool as described in the model overview in Appendix B. The model can assess solutions for the protection or restoration of nutrient-related water quality and allows testing of management scenarios to support cost/benefit evaluations. In addition, once a model is fully functional it can be refined for changes in land-use or embayment characteristics at minimal cost. In addition, since the Linked Model uses a holistic approach that incorporates the entire watershed, embayment and tidal source waters, it can be used to evaluate all projects as they relate directly or indirectly to water quality conditions within its geographic boundaries.

The Linked Model provides a quantitative approach for determining an embayment's: (1) nitrogen sensitivity, (2) nitrogen threshold loading levels and (3) response to changes in loading rate. The approach is fully field validated and unlike many approaches, accounts for nutrient sources, attenuation, and recycling and variations in tidal hydrodynamics

For detailed information on the MEP Linked Watershed Embayment Model, please refer to Appendix B for a description, as the modeling results are not intuitively clear to non-technical community decision makers. SMAST and ACS provided oversight on all model runs for use in preparing the MEP Technical Reports.

Application of the Linked Watershed-Embayment Model

The approach developed by the MEP for applying the linked model to specific sub-embayments, for the purpose of developing target N loading rates, is as follows:

- Select one or two sub-embayments within the embayment system, located close to the inland-most reach or reaches, which typically has the poorest water quality within the system. These are called “sentinel” sub-embayments;

- Use site-specific information and a minimum of 3 years of sub-embayment-specific data to select target/threshold nitrogen concentrations for each sub-embayment. This is done by refining the draft threshold nitrogen concentrations that were developed as the initial step of the MEP process. The target concentrations that were selected generally occur in higher quality waters near the mouth of the embayment system;

- Run the calibrated water quality model using different watershed nitrogen loading rates to determine the loading rate that will achieve the target nitrogen concentration within the sentinel sub-embayment. Differences between the modeled nitrogen load required to achieve the target nitrogen concentration and the present watershed nitrogen load represent nitrogen management goals for restoration and protection of the embayment system as a whole.

Step 3: MassDEP establishes the TMDL

MassDEP utilized the findings of the MEP Technical Report as its basis for establishing nitrogen TMDLs for the MEP's 89 bay embayment systems. The Department utilizes the nitrogen loads from the Technical Report and presents them as daily loads in accordance with the requirements of the Federal Clean Water Act. The TMDL for an affected embayment typically requires very significant watershed reductions in nitrogen loads in the range of 50-80%. They also set watershed-based nitrogen reductions for use in restoring estuarine water quality to its designated uses.

TMDLs are used by MassDEP to set groundwater discharge and NPDES permitting conditions. As stated earlier, the MEP has chosen the restoration of eelgrass or healthy benthic animal communities as the ultimate measure for determining if the TMDL has been met at the designated embayment sentinel station. While specific nitrogen threshold concentrations have been designated as the ambient water column concentration necessary to achieve that level of restoration, the ultimate test will be the concentration that is restorative of habitat, even if the concentration in the estuary is greater than the specified threshold. If the standard has been met and neither eelgrass nor benthic animal communities are restored, then the affected estuary must be re-evaluated to determine what additional strategies are required to achieve the habitat restoration target. At best, the nitrogen threshold concentration for water quality restoration is an estimate, based on water quality conditions that sustain eelgrass beds elsewhere on Cape Cod.

Beyond the restoration of eelgrass because it provides valuable habitat for shellfish and finfish, the other objectives for restoring water quality are to prevent algal blooms, protect benthic communities from impairment or loss and to maintain dissolved oxygen concentrations that are protective of the estuarine communities.

Step 4: Develop the Comprehensive Wastewater Management Plan (nitrogen management plan)

Towns use the TMDL reports as the basis for the nitrogen management planning they would undertake for the reductions they would ultimately propose to the state with the submission of their Comprehensive Wastewater Management Plan (CWMP) (see: http://www.mass.gov/dep/water/laws/wwtrfpg.pdf) .

Traditionally, wastewater management/facility planning has focused on a community-based approach to mitigate the wastewater discharge impacts to affected inland and coastal waters. However, with the introduction of EPA's Total Maximum Daily Load (TMDL) requirement, pollutant load reductions are now required for the watershed as a whole. It is for this reason that the MEP and the TMDL reports do not identify town specific load reductions when two or more towns share a coastal watershed to a nitrogen-impaired embayment.

Step 5: MassDEP Approves CWMP, MassDEP Issues Permit, Applicant Implements CWMP

Following public comment and approval of the CWMP by the Massachusetts Environmental Policy Act (MEPA) Unit (see: http://www.mass.gov/envir/mepa/), MassDEP reviews the applicant's CWMP proposal to determine if the mitigation measures are adequate to address the nitrogen load reductions from the watershed. If approved, the MassDEP prepares a groundwater or surface water (NPDES) permit that defines the requirements and conditions for the proposed layout and design of the wastewater collection, and treatment system. Also defined in the permit are the water quality discharge limits and the water quality/habitat monitoring requirements for determining if compliance with the threshold concentration has been met at the sentinel station(s) in the affected embayment(s).

Following construction of the wastewater infrastructure and the hookup of area homes and businesses, the permittee monitors water quality and habitat conditions in the embayment to determine if the nitrogen reductions were sufficient in restoring water quality. If not, the permittee(s) adjusts their wastewater implementation plan via adaptive management, with MassDEP oversight, or maintains its implementation until the target restoration threshold at the sentinel station in the embayment is achieved.

1.3.6 Natural Attenuation of Nitrogen

Natural attenuation (attenuation or attenuated load) as described in this report, is defined as denitrification, a microbiological process that occurs in anoxic (without oxygen) zones (and all the other conditions necessary for denitrification) in the sediment and sediment-water interface, involving the biological reduction of nitrate (NO3) to nitrogen gas (N2) by the following series of reactions: NO3 to NO2 (nitrite) to NO (nitric oxide) to N2O (nitrous oxide), and finally as a N2 gas emission.

As groundwater flows down gradient to the coast, denitrification occurs as this plume is intercepted by the carbon-rich sediments of one or more lakes and ponds, and/or rivers. MEP research studies have validated this assumption and modeled a 50 percent nitrogen removal in the Linked Model whenever a groundwater plume path is expected to pass through a lake or pond; or a 30 percent reduction whenever the plume is intercepted by a streams and a wetland system. Therefore, the MEP Linked Model assumes 50% removal in ponds and 30% in streams and wetlands associated with them.

An in depth study of over 200 peer-reviewed and other publications was the subject of a MassDEP subcontract under this EPA cooperative agreement to the Woods Hole Group (WHG) and Teal Associates to confirm the role of nitrogen attenuation in different types of wetlands (bogs, fens, emergent, shrub-scrub, wet meadows, cranberry bogs, forested & open wetlands, salt ponds, marshes and mudflats) and waterbodies (streams, rivers, lakes and ponds). Information was also sought from the researchers who have authored previous studies for any unpublished/in press studies. Publications were also sought on the design for constructed wetlands and the site modifications to enhance natural attenuation rates. Finally, the literature review also examined data obtained from model, laboratory, and field projects.

This review identified denitrification in wetlands as the most effective nitrogen removal mechanism from surface and ground water, followed in effectiveness by small ponds, large ponds and streams. Vegetative uptake played only a minor role in nitrogen removal. The role of pH, oxygen content, muck content as a carbon source, stream and/or groundwater flow, and temperature are fully described, each with optimal environmental conditions for promoting nitrate attenuation.

Following the completion of this literature review, the contractor, as a contract deliverable, presented its findings at two public forums: on April 24, 2007 at the Buttonwood Park Zoo in New Bedford, and on April 25, 2007 at the Harwich Community Center. These meetings were well attended and strategically important to the Department and the MEP in providing the public’s point of view on the use of natural and enhanced nitrogen attenuation processes.

This research represented a first step in the policy development process for external and internal discussion concerning the effectiveness, limitations in use, and applicability under existing state statutes and regulations of nitrogen attenuation. The findings of this review of the literature will allow the MassDEP to consider the effectiveness of nitrogen attenuation as a treatment option to reduce impacts from nitrogen-contaminated groundwater that would otherwise contribute to estuarine eutrophication (Appendix J: Executive Summary of WHG Report).

The following copies of this literature review are available for downloading at the MassDEP Website, under Estuaries Project Reports: http://www.mass.gov/dep/water/resources/coastalr.htm.

- Final Report: Natural Attenuation of Nitrogen in Wetlands and Waterbodies,
- Literature Review, Bibliography with Abstracts and Annotations
- Natural attenuation (literature findings as Excel spreadsheet

Key findings of the report are as follows:

1. The most effective nitrogen removal from surface and ground water is via denitrification in wetlands, small ponds, large ponds and streams.
2. The conditions that maximize nitrogen removal include a nitrate loading rate of ~ 2 to 3 mg/l, detention time of about one day in anoxic zones with labile organic carbon, near neutral pH, and temperatures ~ 10° C.

If the natural (microbiological) attenuation capabilities of these ecosystems systems are enhanced or restored, it can be argued that less sewering and wastewater treatment may be needed to meet the nitrogen threshold at the sentinel station in the estuary. However, this view may have unintended consequences; as these wastewater plumes are also sources of phosphate and bacteria, both subject to future TMDL requirements for the affected lakes and ponds.

1.3.7 The MEP Community Partnership

As described earlier the MEP partnership includes the coastal communities of southeastern Massachusetts, the services provided by SMAST, ACRE, the Cape Cod Commission, and MassDEP throughout the CWMP planning and implementation process. For their part, the towns are required to contribute approximately 40% of the overall cost and to provide three years of water quality sampling and monitoring data. The MEP communities must also establish a local committee consisting of officials and citizens who would interface with SMAST and MassDEP staff throughout the planning and implementation phases of comprehensive wastewater management planning.

When the financial considerations for participation are resolved, the MEP process begins at the SMAST designated sampling sites to assess water quality and habitat conditions and eventually for use in calibrating and validating the MEP Linked Model. When the MEP Technical and the MassDEP TMDL reports are completed and the EPA approves the TMDL, MassDEP is ready to provide technical assistance throughout the CWMP decision-making and implementation process.

1.3.8 MEP Resources

Home page for the MEP, including maps and background articles:
http://mass.gov/dep/water/resources/coastalr.htm

Total Maximum Daily Loads (TMDL)
http://www.mass.gov/dep/water/resources/tmdls.htm

Comprehensive Wastewater Management Plans
http://www.mass.gov/dep/water/laws/wwtrfpg.pdf

Water Resource Management Planning http://www.mass.gov/dep/water/laws/iwrmp.pdf

MEP Embayment Restoration and Guidance for Implementation Strategies
http://www.mass.gov/dep/water/resources/mamep.doc

Home page for the MEP Technical Reports at the University of Massachusetts School of Marine Science and Technology (SMAST)
http://www.oceanscience.net/estuaries/

State Bookstore, Room 116, State House Boston, MA 02133 (617) 727-2834
http://www.state.ma.us/sec/spr/spridx.htm

1.4 Applicable Federal, State, County, and Local Roles

1.4.1 Federal Role

1.4.1.1 The Clean Water Act (See 33 U.S.C. § 1251, http://www.epa.gov/watertrain/cwa/) is the federal law that governs the cleanup of impaired inland and coastal waterways, enacted in 1972 with the goal of eliminating the discharge of pollutants to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." To achieve this objective, one of the CWA's principal sections strictly prohibits discharges of pollutants into the "navigable waters of the United States" (see 33 U.S.C. § 1311(a)) without a National Pollution Discharge Elimination System (NPDES) permit from the Environmental Protection Agency ("EPA"). The CWA (see 33 U.S.C. § 1362(7)) defines the term "navigable waters" to mean "waters of the United States, including the territorial seas". For the past thirty years, the control of point, end-of-pipe, wastewater discharges to the environment has been very effective, leaving much of the wastewater discharged from nonpoint sources such as stormwater runoff and on-site waste water treatment plants untouched. The CWA establishes the basis for identifying impaired inland and coastal waters, defining the source(s) of the impairment(s), and defining the reductions in pollutant load to restore water quality that will not exceed the Total Maximum Daily Load (TMDL) (see: http://www.epa.gov/OWOW/tmdl/) The goal of this Rule, as defined in the Clean Water Act, is for the States to work with interested parties to develop Total Maximum Daily Loads or TMDLs for polluted waters. A TMDL is essentially a "pollution budget" designed to restore the health of the polluted body of water for use in swimming, fishing, and healthy populations of fish and shellfish.
(CWA Web page: http://epw.senate.gov/water.pdf)

A statutory and regulatory framework exists in Massachusetts relevant to the implementation of nutrient mitigation measures in support of the information provided by the Massachusetts Estuaries Project.

1.4.1.2 EPA Water Quality Planning and Implementation Grant and Loan Funds. A number of grant programs are available with support provided by the U.S. Environmental Protection Agency; monies that are passed through and administered by MassDEP. These include the following programs that should be considered to assist MEP communities with their nitrogen management planning and implementation activities:

- **Section 319(h) Nonpoint Source Competitive Grants Program**. The federal Clean Water Act amendments (1987) (see: http://www.epa.gov/owow/nps/sec319cwa.html) created a national program to control nonpoint source pollution under § 319 of the CWA (33 U.S.C 1329) to help focus State and local nonpoint source efforts. As administered by MassDEP, 319 funds projects address the prevention, control, and abatement of nonpoint source (NPS) pollution. A 40% match is required from the grantee. Requests for Proposals are generally issued in Spring (see: http://www.mass.gov/dep/water/grants.htm)
- **Section 604b Grant Program Water Quality Management Planning**. As provided by the Clean Water Act, § 604(b), and as administered by MassDEP, 604(b) funds projects for water quality assessment and management planning. Eligible entities include: regional planning agencies, councils of governments, conservation districts, counties, cities and towns, and other substate public planning agencies and interstate agencies. No local match is required. Requests for Proposals are generally issued in mid-October See (http://www.mass.gov/dep/water/grants.htm)
- **Clean Water State Revolving Loan Funds.** Congress created the Clean Water State Revolving Fund (CWSRF) program in 1987 to replace the construction grants program as a long-term funding source for projects that protect and restore the Nation's waters. As in other state programs, the Massachusetts CWSRF oversees construction project financing for wastewater treatment infrastructure projects, including their development, construction, payment, inspection, and closeout. (see: http://www.mass.gov/dep/water/wastewater/cwsrffs.htm)

1.4.1.3 EPA's Stormwater Permitting Program

Stormwater discharges to inland and coastal waters are generated from runoff from land and impervious areas such as paved streets, parking lots, and building rooftops during rainfall and snow events. Runoffs from these sites are a source of nitrogen and other pollutants to coastal embayments in quantities that have the potential to adversely affect water quality and as a result, most stormwater discharges are considered point sources and require coverage by EPA's National Pollution Discharge Elimination System (NPDES) Phase I and Phase II (http://cfpub.epa.gov/npdes/home.cfm?program_id=6) stormwater regulations. The primary method to control stormwater discharges is through the use of best management practices.

Under Phase I, EPA required NPDES permit coverage for stormwater discharges from:

- Medium and large municipal separate storm sewer systems (MS4s) located in incorporated places or counties with populations of 100,000 or more (see: http://cfpub.epa.gov/npdes/home.cfm?program_id=6) ;
- Eleven categories of industrial activity which includes construction activity that disturbs five or more acres of land (see: http://cfpub.epa.gov/npdes/stormwater/swcats.cfm)

Under Phase II, EPA requires NPDES permit coverage for stormwater discharges from:

- Certain regulated small municipal separate storm sewer systems (MS4s) (see: http://cfpub.epa.gov/npdes/stormwater/phase2.cfm) ; and
- Construction activity disturbing between 1 and 5 acres of land (i.e., small construction activities) (see: http://cfpub.epa.gov/npdes/stormwater/cgp.cfm).

1.4.2 State Role

1.4.2.1 Massachusetts Clean Waters Act – M.G.L. Chapter 21, §§26 through 53

Under Massachusetts General Laws Chapter 21, § 27 (see: http://www.mass.gov/legis/laws/mgl/21-27.htm), MassDEP, among its powers and duties is directed to:

- Adopt regulations that MassDEP "deems necessary for the proper administration of laws relative to water pollution and to the protection of the quality and value of water resources…"

- Adopt water quality standards and periodically examine the water quality of MA waters, and to publish the results together with the water quality standards.

- Establish effluent limits, permit programs and procedures applicable to the management and disposal of pollutants, as well as related monitoring, sampling, and reporting requirements for dischargers.

- Conduct a continuing planning process that will result in plans for reducing, controlling and eliminating discharges to all MA waters, and to prepare or supervise the preparation of, and adopt, comprehensive river basin and regional plans "for abatement of such discharges by means of treatment works or other practical control facilities and methods."

- "Encourage" the adoption of water pollution prevention, control, and abatement plans by municipalities and other users of Massachusetts' waters.

Under the Massachusetts Clean Waters Act, MassDEP has the authority to unilaterally establish a wastewater management district (MGL Chapter 21, §§ 28, 29, 30, 32, 35 and 36), and could use this authority to implement solutions on a watershed basis more quickly than might occur by the towns sharing a watershed if they were left to act on their own priorities (see: http://www.mass.gov/legis/laws/mgl/gl-21-toc.htm).

As described in MassDEP's MEP Guidance "Introduction to Management Districts in Massachusetts", (see: http://www.mass.gov/dep/water/wastewater/mgtdists.pdf) MGL Chapter 21, §§ 28-30, 32, 35, and 36 authorize MassDEP to propose, and in some cases, mandate the establishment of water pollution abatement districts consisting of one or more municipalities, or designated portions of one or more municipality. A core power of a water pollution abatement district is to construct, operate, and manage "abatement facilities". The term "abatement facilities" as defined in Chapter 21, § 26A includes "facilities for the purpose of treating, neutralizing, or stabilizing sewage and such industrial and other wastes as are disposed of by means of the facilities, including treatment or disposal plants, the necessary intercepting, outfall and outlet sewers, pumping stations integral to such facilities and sewers, equipment and furnishings thereof and their appurtenances." A district also has an obligation to develop a plan for abating sources of pollution within the district, including identifying the sources of pollution, the means by which and the extent to which such pollution is to be abated, and the facilities needed to abate the pollution. However, these statutory provisions do not specifically address the extent to which a district may abate sources of pollution identified in its plan by means other than an abatement facility owned and operated by the district. To date MassDEP has not exercised its authority under the Massachusetts Clean Waters Act to propose or to require the establishment of a water pollution abatement district.

Pollutant is broadly defined under Chapter 21, §26 as "any element or property of sewage, agricultural, industrial or commercial waste, runoff, leachate, heated effluent, or other matter, in whatever form and whether originating at a point or major nonpoint source, which is or may be discharged, drained or otherwise introduced into any sewerage system, treatment works or waters of the Commonwealth." (Emphasis added.) Note: Neither the MA Clean Waters Act nor the MassDEP existing regulations at 314 CMR further defines what constitutes a "major" nonpoint source. In comparison, the federal Clean Water Act does not regulate or permit discharges from nonpoint sources. Thus, when a TMDL identifies needed reductions in pollutant loadings from nonpoint sources, such reductions may implemented voluntarily when regulations are lacking or under a state law that regulates such discharges. As noted above, MassDEP has state law authority under Chapter 21 to expressly regulate "major" nonpoint sources of pollutants as well as broad authority to promulgate regulations that MassDEP deems necessary for the proper administration of water pollution laws and to protect water resources.

Under Massachusetts General Laws Chapter 21, §43, "no person shall discharge pollutants to Massachusetts waters without a permit from MassDEP, nor shall any person engage in any other activity that may be reasonably expected to result, directly or indirectly, in such a discharge, or construct, maintain, or use a sewer extension or connection without a permit from MassDEP, unless exempted by MassDEP regulation." Chapter 21, §43 directs MassDEP to adopt regulations with respect to permit proceedings and determinations.

1.4.2.2 Title 5: On-Site Sewage Treatment and Disposal Systems

Over 30% of the homes in Massachusetts and over 85 percent on Cape Cod have on-site wastewater systems, as do small businesses and institutions that are located in unsewered areas. Under Massachusetts General Laws (M.G.L.) c. 21A, §13 (http://www.mass.gov/legis/laws/mgl/21a-13.htm) any wastewater treatment that is designed to receive less than 10,000 gallons per day, must comply in accordance with Title 5 requirements (310 CMR 15.000: The State Environmental Code, Title 5, *Standard Requirements For the Siting, Construction, Inspection, Upgrade and Expansion of On-Site Sewage Treatment and Disposal Systems and for the Transport and Disposal of Septage*) (see: http://www.mass.gov/dep/service/regulations/310cmr15.pdf).

While Title 5 is administered by the Department of Environmental Protection ("MassDEP"), pursuant to its authority granted by the State Legislature via M.G.L. c. 21A, §13, (http://www.mass.gov/legis/laws/mgl/21a-13.htm) the Legislature provides local approving authorities, primarily town Boards of Health, with the authority to approve most on-site sewage and disposal systems. Additionally, local authorities may enact more stringent regulations than those required by MassDEP. However, MassDEP is the approving authority for systems owned or operated by the state or federal government, and for systems with a design flow of at least 10,000 gallons per day ("gpd"). These include: innovative/alternative (I/A) systems (http://www.mass.gov/dep/about/organization/aboutbrp.htm#aboutia); shared systems; variances granted by the local approving authority; upgrade or expansion of systems with a design flow between 10,000 and 15,000 gpd; and any other system which MassDEP determines requires its review.

In some situations, a local approval is subject to MassDEP approval. In other instances, local and state authorities may allow a variance (http://www.mass.gov/dep/water/wastewater/faqsupgr.htm#whatvar) from the provisions of Title 5. A variance may be authorized by the state or local approving authority whenever two conditions are met: (1) where the applicant has established that enforcement of the provision of Title 5 would be "manifestly unjust" considering the circumstances of the individual case; and (2) where the applicant has established that a level of environmental protection that is at least equivalent to that provided under Title 5 can be achieved without strict application of the regulations.

If the variance application is approved locally, the applicant must then seek approval from MassDEP. Until then, no work is authorized. Additionally, variance approvals may be conditioned by either the local approving authority or MassDEP with required monitoring and reporting, deed recordation, financial assurances, or other qualifications.

Nitrogen Sensitive Areas - Title 5 regulations (310 CMR 15.214) state, "certain on-site septic systems located in Nitrogen Sensitive Areas, must comply with a wastewater discharge that does not exceed 440 gpd per acre (see: http://www.mass.gov/dep/service/regulations/310cmr15.pdf) . This means a home may not exceed four bedrooms on a one-acre lot or two bedrooms on a half-acre lot. This Commonwealth of Massachusetts Regulation (CMR) affects discharges serving new construction in coastal watersheds to nitrogen sensitive estuaries or other areas designated by MassDEP as nitrogen sensitive, including drinking water supply well zones of contribution defined as 1) Interim Wellhead Protection Areas (IWPAs) and Approved Wellhead Protection Areas (Zone IIs) (see: http://www.mass.gov/dep/water/drinking/wspaglos.htm). The location of these designated Nitrogen Sensitive Areas are mapped and made available to the public. In addition, Title 5 has provisions for designating nitrogen sensitive embayments as nitrogen sensitive areas.

310 CMR 15.216 allows the 440-gpd nitrogen loading limitation to be calculated in the aggregate in two situations. First, one or more municipalities, or a district composed of two or more municipalities, may seek MassDEP approval for an aggregate determination of flows and nitrogen loading across a region-wide area. Local boards of health may thereafter approve site-specific facility aggregation plans in accordance with a MassDEP-approved Community Aggregation Plan. Second, a board of health and MassDEP may approve a site-specific Facility Aggregation Plan that authorizes the 440-gpd limitation to be met across the facility and other land areas for which nitrogen credit is sought.

1.4.2.3 Massachusetts Wetlands Regulations for Stormwater Management

To encourage stormwater recharge, the increased use of low impact development techniques, improved operation and maintenance of stormwater best management practices, and the removal of illicit connections from stormwater management systems, in January of 2008 MassDEP promulgated revisions to the Stormwater Management Standards. The revised Standards have been incorporated into the Wetlands Regulations (310 CMR 10.00) and the addition of new sections. MassDEP has also made some technical changes to 310 CMR 10.00. These revisions are explained further in the new Massachusetts Stormwater Handbook (www.mass.gov/dep/water/laws/policies.htm#storm) and briefly summarized at http://www.ebcne.org/fileadmin/pres/Civian.pdf

1.4.2.4 Groundwater Quality

Under the Massachusetts Clean Water Act (M.G.L. c. 21, § 43) (http://www.mass.gov/legis/laws/mgl/21-43.htm) and the Groundwater Discharge regulations (314 CMR 5.03) discharges of pollutants to the groundwater of the Commonwealth for flows greater than 10,000 gpd are not authorized without a permit by MassDEP. Permit applicants have the option of demonstrating compliance of their discharge or through an alternative nutrient loading approach. In addition to regulating these discharges, the Massachusetts Clean Water Act (M.G.L. c. 21, §§ 26 through 53) also require that MassDEP regulate the outlets for these discharges and any treatment works associated with the discharges.

These permitted discharges must also comply with the Massachusetts Groundwater Quality Standards (314 CMR 6.00) that establish classifications, water quality criteria, and designated uses for groundwater. MassDEP is authorized to establish effluent limits in groundwater discharge permits. MassDEP also has broad authority under 314 CMR 6.07 to subject its groundwater discharge permits to “such conditions as [MassDEP] may deem necessary to insure compliance” with the minimum groundwater quality criteria (see: http://www.mass.gov/dep/service/regulations/314cmr06.pdf).

1.4.2.5 Surface Water Quality

Under the Massachusetts Clean Water Act (M.G.L. c. 21, § 27) (http://www.mass.gov/legis/laws/mgl/21-27.htm) and the Massachusetts Surface Water Discharge Permits Quality Standards (314 CMR 3.03) discharges of pollutants to the surface waters of the Commonwealth are not authorized without a MassDEP permit. Under 314 CMR 3.06, MassDEP may also issue general permits that regulate one or more categories of surface water discharges by multiple dischargers who have applied for coverage under the general permit (see: http://www.mass.gov/dep/service/regulations/314cmr03.pdf).

These permitted surface water discharges must also comply with the Massachusetts Surface Water Quality Standards (314 CMR 4.00) which designate the most sensitive uses for which "the waters of the Commonwealth shall be enhanced, maintained and protected; prescribe the minimum water quality criteria required to sustain the designated uses; and contain regulations necessary to achieve the designated uses and maintain existing water quality" (see: http://www.mass.gov/dep/service/regulations/314cmr04.pdf).

Under 314 CMR 4.03, MassDEP may limit or prohibit surface water discharges to assure compliance with the water quality standards. In establishing effluent limits, MassDEP must consider background conditions and existing discharges. MassDEP also has authority to limit or prohibit discharges to protect existing uses and to prevent interference with the attainment of designated uses in downstream and adjacent segments.

1.4.2.6 Massachusetts Coastal Zone Management Program

"The mission of the Massachusetts Office of Coastal Zone Management (CZM) is to balance the impact of human activities with the protection of coastal and marine resources through planning, public involvement, education, research, and sound resource management." Through its Coastal Nonpoint Pollution Control Program CZM carries out its mission through technical assistance and funding support to communities within the coastal zone through a grant programs that support the implementation of the Coastal Nonpoint Pollution Control Program: (see: http://www.mass.gov/czm/cwq.htm)

- The Coastal Pollutant Remediation (CPR) Grant Program, provides funding to municipalities in Massachusetts coastal watersheds to reduce stormwater impacts from roads, highways, or parking areas and to install municipal boat pumpout facilities (see: http://www.mass.gov/czm/cprgp.htm).

The Massachusetts CZM also hosts two of the US Environmental Protection Agency's National Estuary Program projects as an advisory and planning unit. These include the Buzzards Bay (http://www.buzzardsbay.org/index.htm) and the Massachusetts Bays (http://www.mass.gov/envir/massbays/default.htm) National Estuaries Programs. The Buzzards Bay NEP serves the Buzzards Bay Watershed communities while the Massachusetts Bays NEP serves the communities bordering Massachusetts Bay and Cape Cod Bay. Similar to the other NEP projects nationwide, they are guided by the Clean Water Act Section 320 (http://www.epa.gov/owow/estuaries/320.htm) which requires them to develop plans for attaining or maintaining water quality in an estuary. Similar to the MEP, they use a science-based approach to inform decision-making, emphasize collaborative problem solving, and involve the public. As required, each program establishes a Comprehensive Conservation and Management Plan (http://www.epa.gov/owow/estuaries/ccmp/index.htm) to control point and nonpoint sources of pollution to supplement existing controls of pollution and is developed and approved by a broad-based coalition of stakeholders. The Buzzards Bay (http://www.buzzardsbay.org/ccmptoc.htm) and Massachusetts Bay (http://www.mass.gov/envir/massbays/ccmp.htm) CCMP serve as a blueprint for coordinated action to guide future decisions and actions and addresses a wide range of environmental protection issues including water quality, habitat, fish and wildlife, pathogens, land use, and introduced species to name a few. To carry out its objective, each CCMP features action plans with specific recommendations for pollution prevention, habitat preservation, and the restoration of the Bays degraded resources that would be carried out by dozens of organizations, both governmental and non-governmental, each responsible for taking the steps needed to protect and restore the Bays.

MEP Technical and Financial Support. Both NEP programs provide funding and technical assistance support to municipalities and citizens to implement the recommended actions contained in the Management Plan. MEP communities served by these two projects should take advantage of the technical support they provide associated with CWMP planning and implementation. The can provide grant writing services for the planning and implementation projects available from the MassDEP and CZM grant programs identified in this report. MEP communities located within the watershed areas of these NEP's should consider the consultant type of services they provide communities in any stage of watershed-based nitrogen management planning; including their use in bringing communities together to address the possibilities of joint, intermunicipal watershed-wide nitrogen reductions.

1.4.3 County Role

Barnstable County has taken a number of initiatives that address the importance of assisting the towns with the preparation and financing of wastewater management plans following the approval of a TMDL by the US Environmental Protection Agency. These initiatives by the Barnstable County Health and Environment Department (BCHDE), Cape Cod Commission, Wastewater Implementation Committee, and the Cape Cod Water Protection Collaborative are briefly described below. Consult their websites for more information.

1.4.3.1 Barnstable County Health and Environment Department and the Massachusetts Alternative Septic System Test Center

The Barnstable County Health and the Environment Department (BCHDE) and its 15 municipal boards of health have been actively investigating, since the early 1990s, the feasibility of enhancing the capacity of septic systems to remove nitrogen. Since 1995 when MassDEP revised its Title 5 regulations (310 CMR 15.000) "innovative and alternative (I/A)" systems were allowed for the disposal and treatment of wastewater. As a result of this revision, since 1999, more than 1,100 I/A systems were installed on Cape Cod (Heufelder, Rask, and Burt 2007).

The Massachusetts Alternative Septic System Test Center, located at the Otis Air National Guard Base on the Massachusetts Military Reservation on Cape Cod, led by The Buzzards Bay National Estuary Program (BBP), in collaboration with Massachusetts Department of Environmental Protection (MassDEP), BCDHE, and UMass Dartmouth's School of Marine Science and Technology (SMAST), was established to field test the performance of proposed I/A systems as part of the testing and approval process provided by the 1995 Title 5 revisions. In addition, the Center identified the operational costs of these new innovative technologies and assists vendors in getting their technologies approved for use in Massachusetts.

A report by the BCHDE, in conjunction with the 15 Boards of Health in Barnstable County, recently presented the results of many pilot studies that defined the performance of several nitrogen-removal I/A systems on Cape Cod soils. A copy of this report "Performance of I/A onsite septic systems for the removal of nitrogen in Barnstable County, Massachusetts 1999-2007" is available for downloading at: http://www.buzzardsbay.org/etimain.htm

In addition to their work at the Test Center, the BCHD is currently engaged in a two-year study, entitled: "Developing of Smart Growth Planning tools to deal with gross impact of sewering" with funding provided by the Massachusetts Environmental Trust. In 2007, the first year of the study, a working group was convened with representation from the towns with a focus on promoting public education on wastewater and sewering issues.

1.4.3.2 Cape Cod Commission

Since its founding in 1990, the Cape Cod Commission has administered a No Net Nitrogen (NNN) Policy for Developments of Regional Impact or DRIs (new retail, office, industrial or private construction greater than ten thousand square feet, additions greater than five thousand square feet, or outdoor commercial space greater than forty thousand square feet, and any proposed development, including the expansion of existing developments, that is planned to create or accommodate more than thirty dwelling units). Website: http://www.capecodcommission.org/RPP/home.htm

The regional No Net Nitrogen Policy requires that DRIs when proposed in ground watersheds with documented marine water quality problems or defined as nitrogen sensitive must maintain or improve existing nitrogen loadings. Developments may meet this requirement by providing additional wastewater treatment capacity for nearby dischargers, installing denitrifying on-site wastewater systems for existing septic systems, and/or contributing financially to town or watershed planning that support nitrogen reduction efforts.

1.4.3.3 Wastewater Implementation Committee

Barnstable County Commissioners established the Wastewater Implementation Committee (WIC) in 2002 as an advisory committee to the County on countywide wastewater management planning and as a regional forum for "sharing information and coordination between towns, county and state programs. As a regional forum on wastewater management, its goal was to identify opportunities for consensus among its stakeholders that would lead to a new regional wastewater management plan; including options for establishing Wastewater Management Districts for use in determining which are most appropriate for town consideration. The WIC goals were ambitious in facilitating and encouraging towns to initiate wastewater management strategies that protect public health, restore coastal and fresh surface water quality, preserve community character and provide growth center infrastructure." Website: http://www.capecodgroundwater.org/wastewaterpages/wastecom.html

In 2004 the WIC published study "Enhancing Wastewater Management on Cape Cod: Planning, Administrative, and Legal Tools", conducted by a WIC working group led by Wright-Pierce and other consultants, conducted four case studies involving the towns of Barnstable, Orleans, Mashpee, and Falmouth concerning their capabilities and limitations to address future needs for wastewater management. (see: http://www.capecodcommission.org/water/WastewaterToolsReport/WWToolsRept.pdf) Because of this effort the WIC working group recommended several planning, administrative and legal tools and actions for consideration/follow-up by the towns, the county and the state. For Mashpee, the Study highlighted the potential benefits and challenges presented by the large number of private sewage treatment facilities serving commercial and residential developments. On one hand, these facilities have prevented further nitrogen loadings to the estuary, and in the future can be part of the town's wastewater structure. However, they were built as standalone facilities without considering municipal or watershed needs, and the technology used may not be what the town would have chosen.

In 2005, thirty thousand dollars ($30,000) was awarded and allocated between the Towns of Eastham and Wellfleet for a study on the use I/A wastewater disposal systems for mitigating nitrogen-loading impacts.

1.4.3.4 Cape Cod Water Protection Collaborative

The Cape Cod Water Protection Collaborative, (http://www.capekeepers.org/) created in 2005 through ordinance by the Barnstable County Assembly of Delegates inherited the work of the WIC with the goal of addressing the inadequacy of the Cape's wastewater infrastructure to mitigate wastewater discharge impacts to its inland and coastal waters. (see: http://www.barnstablecounty.org/documents/05-22WasteColl.DOC

As stated in its authorizing legislation, the Collaborative is "To offer a coordinated approach to enhance the wastewater management efforts of Towns, the Regional Government and the Community for the provision of cost-effective and environmentally sound wastewater infrastructure, thereby protecting Cape Cod's shared water resources". In addition, it is charged to: "1) Attract state, federal and public-private revenue sources for financing assistance to the Towns for wastewater projects; 2) Maximize regional cooperation and action in managing wastewater; 3) Coordinate the development of infrastructure that is cost-effective, technologically efficient and environmentally appropriate; and 4) Educate the public concerning the contribution wastewater management makes to sustaining Cape Cod's economic and environmental health."

In addition, the Collaborative assists the Cape's towns prepare and adopt comprehensive wastewater management plans within three years of receiving the TMDL data from MassDEP; ensuring the plans are consistent with the Regional Wastewater Management Plan.

1.4.4 Local Role

Citizen-monitoring groups, regional planning and environmental organizations, and city/town agencies (e.g., Selectmen, City councils, Boards of Health, Planning Boards, and Departments of Public Works) all have a role when it comes to the implementation of wastewater management related measures for their community. It may be in the form of promoting public education on the issues of concern or more specifically related to needed planning, funding, zoning, and/or regulatory measures. Under Massachusetts General Law, cities and towns have local options to address land use nitrogen reductions, many of which are discussed in the MEP Embayment Restoration and Guidance for Implementation Strategies at http://www.mass.gov/dep/water/resources/mamep.doc. This MEP report provides useful information covering the following topics:

- Wastewater Treatment
  - On-Site Treatment and Disposal Systems
  - Cluster Systems with Enhanced Treatment
  - Community Treatment Plants
  - Municipal Treatment Plants and Sewers
- Tidal Flushing
  - Channel Dredging
  - Inlet Alteration
  - Culvert Design and Improvements
- Stormwater Control and Treatment *
  - Source Control and Pollution Prevention
  - Stormwater Treatment
- Attenuation via Wetlands and Ponds
- Water Conservation and Water Reuse
- Management Districts
- Land Use Planning and Controls
  - Smart Growth
  - Open Space Acquisition
  - Zoning and Related Tools
- Nutrient Trading

Massachusetts General Laws Chapter 111, § 31 (http://www.mass.gov/legis/laws/mgl/111-31.htm) provides broad general powers to municipal boards of health to promulgate reasonable regulations that can exceed the State's minimum Title 5 requirements, provided that the board states the reasons and/or local conditions supporting the more stringent regulation at a public hearing.

Towns are enabled to address nitrogen reductions through other existing authorities and measures, including but not limited to:

- Adopting local bylaw/ordinances for coastal watersheds that have been defined and mapped as nitrogen sensitive that limits the onsite disposal systems to 440 gallons per day per acre nitrogen loading or no more than four bedrooms (110 gallons per day/bedroom) pursuant to 310 CMR 15.214 (http://www.mass.gov/dep/service/regulations/310cmr15.pdf).

- Adopting local bylaws/ordinances to manage fertilizer (see: http://www.mass.gov/dep/water/resources/fertiliz.htm), pursuant to 310 CMR 15.216 (see http://www.mass.gov/dep/water/nagg95p.doc).
- Adopting local bylaws/ordinances requiring water reuse by dischargers
- Adopting local bylaws/ordinances related to house drainage, pursuant to Chapter 111, §127 (http://www.mass.gov/legis/laws/mgl/111-127.htm).
- Adopting a bylaw that mandates Title 5 upgrades to I/A systems. (http://www.mass.gov/dep/water/wastewater/iatechs.htm) for Zone IIs and Nitrogen Sensitive Areas that are more restrictive than Title 5 (see http://www.mass.gov/dep/water/nagg95p.doc).
- Adopting local bylaws/ordinances that address aquatic buffers, erosion and sediment control, open space development, storm water control operation and maintenance, illicit discharges, and post construction controls. (see: http://www.epa.gov/owow/nps/ordinance and http://www.stormwatercenter.net/).
- Deciding areas to sewer and mandating owners of abutting property to connect to a common sewer, pursuant to Chapter 83 §3 (http://www.mass.gov/legis/laws/mgl/83-3.htm) and §11 (http://www.mass.gov/legis/laws/mgl/83-11.htm).
- Requiring ongoing system management in the disposal system construction permits , (http://www.mass.gov/dep/water/t5form2a.pdf) pursuant to 310 CMR 15.003. (http://www.mass.gov/dep/service/regulations/310cmr15.pdf).
- Issuing and enforcing Conservation Commission Orders of Conditions, (http://www.mass.gov/dep/water/approvals/wpaform5.pdf) pursuant to 310 CMR 10.00 (http://www.mass.gov/dep/service/regulations/310cmr01.pdf).

Additionally, towns may address nitrogen reductions through an inter-municipal wastewater district. This can be accomplished through a Comprehensive Water Resources Management Plan that identifies the wastewater infrastructure and management needs for a watershed shared by more than one town. CWMP's not only propose a plan, they also investigate the need for the proposed facilities, consider alternatives, and must be approved by MassDEP. A MassDEP approved CWMP consists of the following elements:

- A description of the proposed treatment works, and the complete collection and wastewater treatment system of which it is a part
- A description of the Best Practicable Wastewater Treatment Technology
- A cost-effective analysis of the feasible conventional, innovative and alternative wastewater treatment works, processes and techniques
- A cost-effective planning period of 20 years
- A demonstration of the non-existence or possible existence of excessive infiltration/inflow in the sewer system
- An analysis of the potential open space and recreation opportunities associated with the project
- An evaluation of the environmental impacts of alternatives to meet the requirements of MEPA
- An evaluation of the water supply implications of the project
- For the selected alternative, a concise description
- A public participation program that includes as a minimum one public meeting to discuss the alternatives and their environmental impact and a public hearing on the recommended plan including its environmental impact.

If these elements are present, the MassDEP may approve an inter-municipal wastewater management district's plan.

MassDEP's guidance document: "Guide to Comprehensive Wastewater Management Planning" (http://www.mass.gov/dep/water/laws/wwtrfpg.pdf) and at 310 CMR 44 which defines MassDEP's authority and responsibilities to select, approve and regulate water pollution abatement projects receiving financial assistance under the State Revolving Fund ("SRF") Program should be consulted to assist municipal officials, consulting engineers, citizens groups, and other interested parties in developing comprehensive wastewater management plans. (see: http://www.mass.gov/dep/service/regulations/310cmr44.pdf)

For alternative residential development planning patterns that are protective of coastal waters, readers may want to consider the recommendations provided by National Oceanic and Atmospheric Administration's (NOAA) Coastal Services Center at its website: http://www.csc.noaa.gov/alternatives.

1.5 Wastewater Treatment and Effluent Discharge Siting

The location of treatment plant discharges is an increasingly challenging issue for MEP communities, given the space limitations at preferred sites where housing densities favor a treatment facility and the prohibition under the Massachusetts Ocean Sanctuaries Act ((M.G.L. c132A section 15-16) from siting new surface water discharges in Nantucket Sound or to Massachusetts Bay (see: http://www.mass.gov/legis/laws/mgl/132a-15.htm)

Section 14A of the Ocean Sanctuaries Act states the ocean sanctuaries "… shall be protected from any exploitation, development, or activity that would significantly alter or otherwise endanger the ecology or the appearance of the ocean, the seabed, or subsoil thereof, or the Cape Cod National Seashore". As a consequence, NPDES permits are not allowed; requiring all future wastewater treatment facilities to discharge treated wastewater flows to the subsurface environment, once the CWMP proposal for a wastewater treatment works has been approved and permitted as a MassDEP groundwater discharge permit.

1.6 Watershed-Based Permitting and Nutrient Trading in this Project

Watershed based permitting and nutrient trading are important tools to improve water quality. EPA has led the way in promoting their use, and has developed policies and guidance to help states and communities use them appropriately.

EPA's primary interest in funding this grant to MassDEP was to understand how watershed-based permitting and nutrient trading can support implementation of the nitrogen loading limits established by the Massachusetts Estuaries Project (MEP). Both the state and municipalities will play critical roles: Communities will determine how these tools fit into local TMDL implementation plans.
MassDEP will evaluate changes needed in state regulations or permitting to support them.

Lessons learned from this project will help other communities in Massachusetts and other states determine how best to use watershed-based permitting and nutrient trading.

1.6.1 What is Watershed-based Permitting?

Watershed-based permitting is a tool to address all point and nonpoint sources of pollution within a geographic area, rather than issuing permits to individual pollution sources. Watershed-based permitting can range from synchronizing the timing of permits within an estuary to issuing a single permit that regulates all discharges. For more information, see EPA material: http://cfpub.epa.gov/npdes/wqbasedpermitting/wspermitting.cfm)

The right approach to watershed-based permitting depends on circumstances in each watershed, sources of nitrogen, and the structure and flexibility of federal, state, and local regulatory systems. For example, EPA is particularly interested in watershed-based permitting as it relates to NPDES permits for surface water discharges. MassDEP is interested also in permits issued under the Commonwealth's groundwater and on-site discharge regulations.

In addition to determining the appropriate watershed-based permitting for the three pilot estuaries, this project will identify the regulatory and permitting obstacles in Massachusetts to implementing watershed-based permitting and develop a road map to address them. The road map could include changes in state regulations, new legal entities at the local level for permitting purposes, new permitting and enforcement tools for communities, and other options.

1.6.2 What is Nutrient Trading?

Nutrient trading is an approach to meeting water quality goals by identifying the most cost-effective ways to reduce pollution and using financial incentives to encourage reductions by as many dischargers as possible. According to the EPA, "Trading can provide greater efficiency in achieving water quality goals in watersheds by allowing one source to meet its regulatory obligations by using pollutant reductions created by another source that has lower pollution control costs." For more information: http://www.epa.gov/owow/watershed/trading.htm

A nitrogen trading program relies on: 1) the commodity that will be traded; 2) a demand for the commodity; and 3) a structure for trading the commodity. In this report, the commodity for trading is the kilograms of nitrogen that the MEP Linked Model calculated scientifically for reduction from the watershed that would ultimately achieve the nitrogen threshold concentration for restoring water quality in the estuary. For the purpose of this report, the watershed-wide nitrogen loads that have been quantified for reduction by the Massachusetts Estuaries Project for each sub-watershed and town sharing this coastal watershed provided the basis for inter-municipal discussions regarding wastewater management planning and implementation that is cost and environmentally effective for restoring water quality by the participating communities.

In Massachusetts, the trading tools used are variable and dependent on local circumstances. For example, a nutrient offset program or trading is used whenever a wastewater facility applies for a new or increased wastewater discharge to a nitrogen sensitive coastal watershed. Typically, the nitrogen offset program is applied to individual projects requiring a discharge permit in areas without a comprehensive wastewater management plan (CWMP) in order to insure that no additional nitrogen is applied to an impacted watershed. In these circumstances, approval is granted in exchange for sewering a sufficient number of on-site septic systems so that, at a minimum, the outcome of the permit to expand results in a watershed reduction of nitrogen to the estuary. More complex trading tools do exist elsewhere that utilize formal nutrient trading markets, in which sources of pollution buy and sell credits for pollution discharges. Whatever tool is use, it is clear that EPA has made it clear in its draft framework for watershed-based trading (1996) that trades must be consistent with attainment of water quality standards and occur within a regulatory (permitting), enforcement, public participation framework. The EPA also stressed that the boundaries of trading should generally coincide with watershed or water body segment boundaries. This correlation ensures that the environmental outcomes of trading between parties occur within the boundaries of the same watershed that the boundaries are of manageable size, and are selected to prevent localized problems.

In this project, the participating Case Studies communities utilized the findings of the MEP as the basis for resolving how they would "trade" or share responsibility for the nitrogen load reductions they are responsible under EPA's watershed-based TMDL. At the same time MassDEP and the Pilot Project Teams utilized what was learned from these Case Studies to identify changes in state policy and regulations to facilitate inter-municipal, watershed-based TMDL planning and implementation.


Typical Algae Bloom

Chapter 2: Popponesset Bay Pilot Project

Figure 2.1 Aerial view of Popponesset Bay showing the sand spit that impedes tidal exchange with Nantucket Sound

2.1 Popponesset Bay Watershed Facts

Key Feature	TMDL implementation in a tidal estuary
Project Name	Popponesset Bay Watershed, Inter-municipal Watershed TMDL Implementation
Scope/Size:	Watershed area: 20.5 square miles (ca. 12,942 acres); approximately 9 miles north to south and just over 3 miles east to west.
Land Type	18 % Rural undeveloped, urbanizing with 36% residential, 2% limited agriculture including golf course, 9% ponds and lakes, and 35% municipal, pubic and private open space.
Pollutant	Nitrogen
Wastewater Infrastructure	Watershed is without municipal sewer; 5 private sewage treatment plants; most properties with residential on-site wastewater disposal systems.
Hydrology	The Popponesset Bay system consists of five embayments (Popponesset Bay, Pinquickset Cove, Ockway Bay, Mashpee River, and Shoestring Bay) and three Rivers with surficial flow from the watershed (Mashpee River, Santuit River and Quaker Run). This embayment system exchanges tidal water with Nantucket Sound through a single maintained inlet at the tip of Popponesset Bay. *
TMDL Development	NPS subsurface, nitrogen discharges primarily from residential on-site septic systems and secondarily from fertilizers use associated with cranberry bogs and golf course turf management.
Data Sources	Towns of Mashpee, Barnstable, and Sandwich; Cape Cod Commission; Mass. Department of Environmental Protection; University of Massachusetts @ Dartmouth-School of Marine Science & Technology (SMAST)
Data Mechanisms	Water quality monitoring results, watershed/parcel specific defined estimates of nitrogen loading based on drinking water use records, USGS delineation groundwatersheds, and MEP Linked Watershed-Estuary Nitrogen Management Model (Linked Model) for calculating load thresholds.
Monitoring Plan	Yes
Control Measures	In 2001, the Town of Mashpee initiated comprehensive wastewater planning to reduce the sources of watershed nitrogen loads affecting the Popponesset Bay system and its embayments. Planning is underway to prepare a comprehensive wastewater management plan with input from the neighboring towns of Barnstable and Sandwich. At the time of this report, Barnstable has initiated its planning while Sandwich has not.

* A complete description of all 5 sub-embayments is presented in Chapters I and IV of the MEP Technical Report

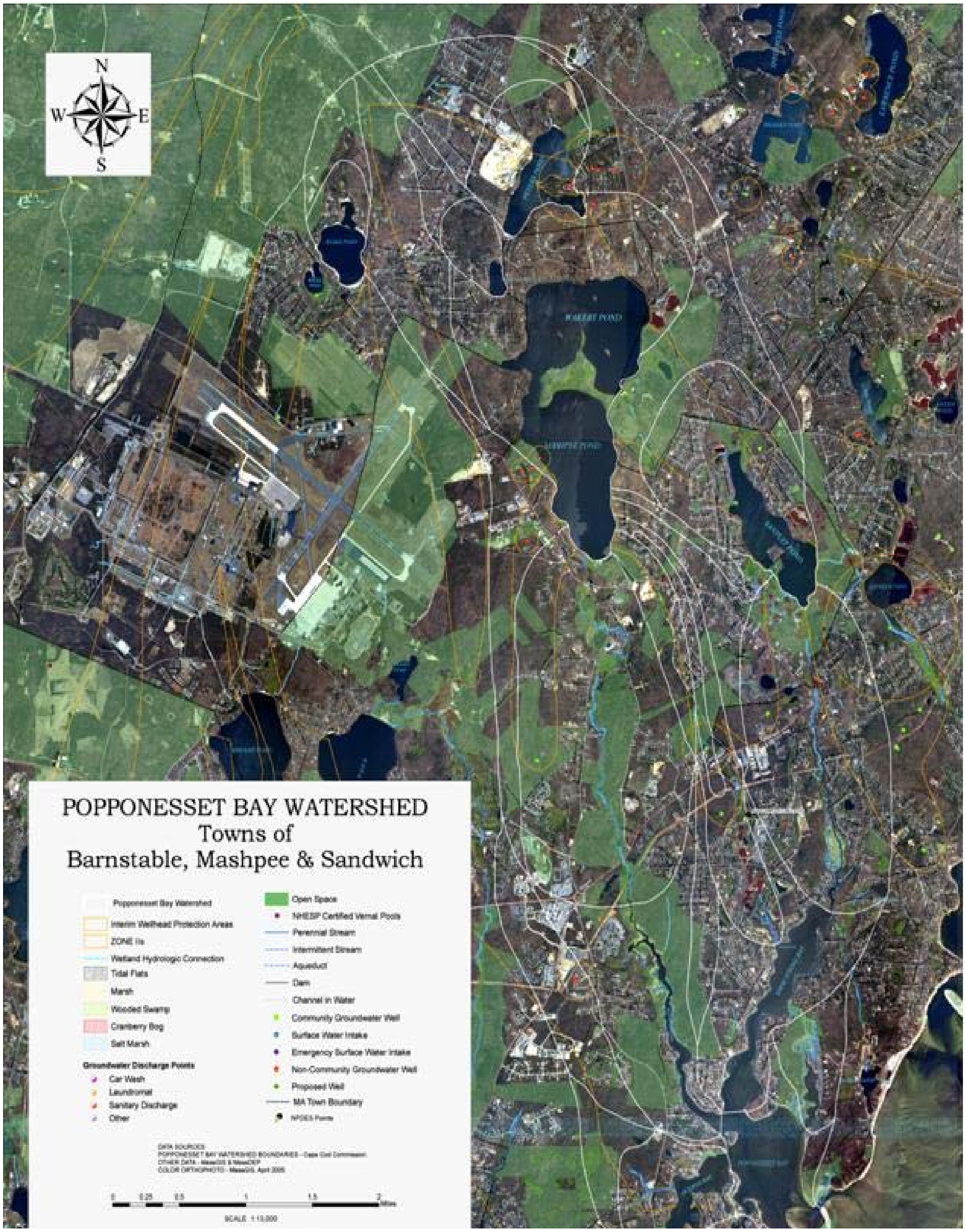


Figure 2.2 Delineation of the Popponesset Bay Watershed

2.2 The Popponesset Watershed

2.2.1 General Description

The Popponesset Bay Watershed and its five embayments (Popponesset Bay, Pinquicket Cove, Ockway Bay, Mashpee River, and Shoestring Bay) lie along the southern shores of the Cape Cod Basin. Three estuarine river systems (Mashpee River, Santuit River, and Quaker Run) discharge directly to the Bay and the Bay ultimately discharges to Nantucket Sound through a single outlet (Figure 2.1). As shown in Figure 2.3, the five embayments are subdivided further into two or more sub-embayments.

These embayments constitute important components of each Town's natural and cultural resources. However, the nature of these enclosed embayments in close proximity to populous regions of the watershed brings two opposing elements to bear: (1) as protected marine shorelines they are popular for boating, recreation, and land development and (2) as enclosed bodies of water, the pollutants they receive may not be readily flushed. In particular, the sub-embayments within the Popponesset Bay Watershed are at risk of further eutrophication from high nutrient loads in the groundwater and runoff from their watersheds. Because of excessive nutrient discharges, the Mashpee River, Shoestring Bay, and Popponesset Bay embayments have been listed as impaired waters requiring TMDLs (Category 5) in the MA 2006 Integrated List of Waters (http://www.mass.gov/dep/water/resources/2006cmt2.pdf).

The watershed drainage area consists of 13,458 acres (21.029 sq miles) and slightly over 9 miles north and south and just over 3 miles east and west. The Popponesset Bay embayment is roughly 1 mile long and a slightly over half a mile wide - shore-to-shore (Figure 2.3, No. 26). The land area of the watershed is shared with the towns of Mashpee, Barnstable (Cotuit Village), and Sandwich. Nearly two thirds of the 21 square mile watershed area is within Mashpee, followed by lesser amounts by the towns of Sandwich and Barnstable (Table 2.1).

Table 2.1 Popponesset Watershed Land Area by Town

TOWN	Town Area within Popponesset Watershed		
	Acres	Square Miles	Percent
Barnstable	1,469.236	2.296	10.92%
Mashpee	8,573.633	13.397	63.71%
Sandwich*	3,414.999	5.336	25.37%
Total	13,457.868	21.029	100.00%

* Area includes all water, including estuarine

The Massachusetts Military Reservation has 369 acres ~ 10.8% within the Town of Sandwich and 2.74% of the land area within the Popponesset Watershed.

This southern coastal region of Cape Cod between the Popponesset Bay and West Bay entrances can be considered a moderately dynamic region, where natural wave and tidal forces continue to reshape the shoreline. Due to the protection afforded by the islands of Martha's Vineyard and Nantucket, the south shore of Cape Cod is protected from the influence of long period open ocean wave conditions. Similar to many portions of the Massachusetts coast, the available sediment supply influences the migration and/or stability of tidal inlets. Tidal inlets can become overwhelmed by the gradual wave-driven migration of a barrier beach separating the estuaries from the ocean. In addition to these natural coastal processes, man-made structures often can influence the stability of a shoreline/tidal inlet system.

2.2.2 Geology and Hydrogeology

The hydrogeology of this watershed, like most of Cape Cod, consists predominantly of glacial deposits of sand and gravel. Several glacial kettle-hole ponds characterize the Mashpee River subwatershed while a small glacial pond and large kettlehole pond (Santuit Pond) define the Santuit River subwatershed (see: http://www.capecodgroundwater.org/groundwateredpage/groundwater.pdf).

Unlike off Cape locations where surface topographic features characterize a watershed's boundary and drainage pattern, Cape Cod's ground watersheds are defined by the elevation and direction of flow of its water table (Cambareri and Eichner 1998, Millham and Howes 1994 a, b). The Sagamore Lens is the contributing source of the Popponesset Bay groundwater (see: http://simlab.uri.edu/cara/sagamore.htm). The aquifer's convex shape causes it to resemble a lens and it is often referred to as the freshwater lens. Popponesset's embayments are of varying size and hydraulic complexity; each defined by their rates of flushing, salinity, and shallow depths and their proximity to a heavily developed and populated sub-watershed.

2.2.3 Water Quality

Water quality studies have been ongoing since the early 1980s when the DEQE (now MassDEP) Shellfish Sanitation Section (now delegated to the Massachusetts Division of Marine Fisheries) identified excessive levels of coliform bacterial contamination in the Mashpee River. Following this discovery, the DEQE ordered the closure of the Mashpee River to shell fishing. This finding prompted Mashpee to conduct additional water quality studies by its consultant and the work of others:

- October 1987. "Sources of Bacterial and Nutrient Contamination into the Mashpee River, Santuit River and Shoestring Bay" (KV Associates, Inc.)
- 1988. To evaluate the impacts from stormwater discharges (under winter conditions) and the delineation of the recharge zone to the Mashpee River, Quaker Run and the Santuit River.
- July 1988. The Sewer Commission in conjunction with its work for a proposed a sub-regional wastewater treatment plant adjacent to the Mashpee landfill, commissioned a study to identify flow and water quality conditions of the Mashpee River. This study concluded that Popponesset Bay and its embayments were degraded by nutrient additions and classified the embayment system eutrophic.
- 1991. "A Cumulative Impact Assessment Plan to Reduce and Control Sources of Contamination in the Mashpee and Santuit/Shoestring Bay River Estuaries" (KV Associates, Inc.) A modeling study for use in providing long-term management in preserving water quality of the Mashpee River and Shoestring Bay.
- 1997 and 1998. "Nutrient Related Water Quality within the Popponesset Bay System, Part I: Summer Survey of Nutrient and Oxygen Levels" (Howes, B. and David Schlezinger). This study assessed if nutrient-related water quality impairment was affecting the Popponesset embayment system. The Mashpee River, Ockway Bay, and Shoestring Bay were identified with nutrient related water quality impacts.
- 1993. "The Cape Cod Coastal Embayment Project Study" (Cape Cod Commission) funded with EPA section 319 MassDEP pass through money, was among the first to document water quality degradation to Popponesset Bay with sub-watershed nitrogen loads.
- 2002. "Cape Cod Coastal Nitrogen Loading Studies" by the Cape Cod Commission, funded by MassDEP through Clean Water Act section 604b grant (#99-03/604). Using the results of 604b-funded water quality studies from the mid to late 1990s, this study revised tidal flushing studies in the Popponesset Bay system including the Mashpee River to produce nitrogen management options for the watershed.
- 2004. "Popponesset Technical Report" (MEP) Evaluated the full extent of the watershed impacts on the Popponesset Bay system based on 1997 – 2003 water quality studies.

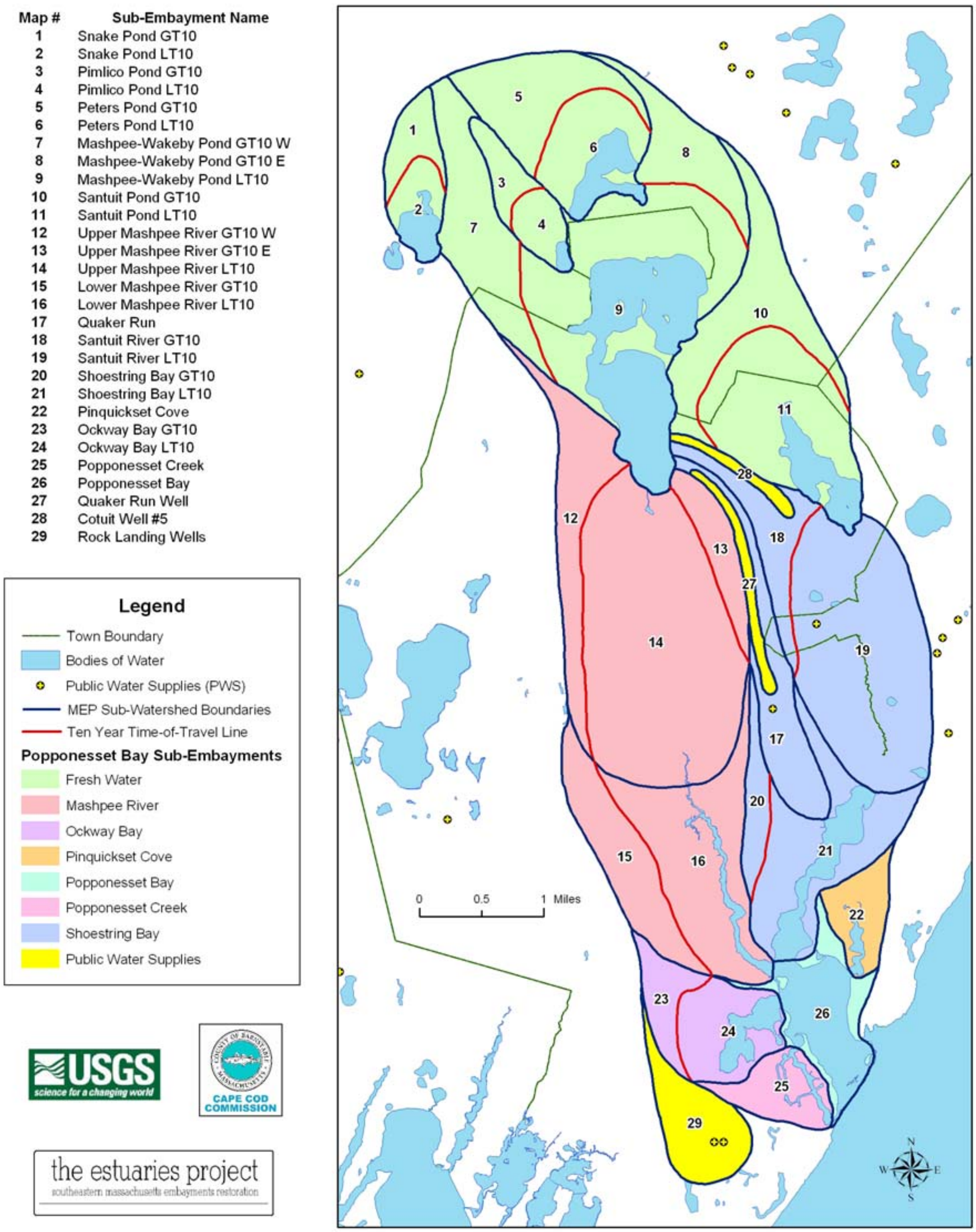


Figure 2.3 The Popponesset Bay Watershed and its Groundwatersheds

The MassDEP Cape Cod Watershed Water Quality Assessment Report to EPA initiated studies of the Popponesset Bay, Mashpee River and Shoestring Bay embayments to assess their status as SA waters (see: http://www.mass.gov/dep/water/resources/96wqar.pdf). This designation, as defined by the MassDEP Surface Water Quality regulations (314 CMR 4.05(4)(a)), means these waters are:

> "…. an excellent habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. In certain waters, excellent habitat for fish, other aquatic life and wildlife may include, but is not limited to, seagrass. Where designated in the tables to 314 CMR 4.00 for shellfishing, these waters shall be suitable for shellfish harvesting without depuration (Approved and Conditionally Approved Shellfish Areas). These waters shall have excellent aesthetic value"

In view of the past and recent water quality studies that confirmed water quality degradation, the Mashpee River, Shoestring Bay, and Popponesset Bay sub-embayments are listed as impaired waters on the Massachusetts 2006 Integrated List of Waters (http://www.mass.gov/dep/water/resources/2006cmt2.pdf) that require TMDLs (Category 5) to comply with the Clean Water Act under Section 303(d) (Table 2.2). The environmental damage affecting the Popponesset, Mashpee River and Shoestring Bay embayments include pollutant loadings from nutrients and pathogens, periodic decreases of dissolved oxygen, decreased diversity of benthic animals, and periodic algal blooms.

Habitat quality of the Popponesset Bay System is highest near the tidal inlet to Nantucket Sound and poorest in the inland-most tidal reaches. This is indicated by gradients of the various indicators. For example, nitrogen concentrations are highest inland and lowest near the mouths. In addition, the nitrogen loads from the contributing sub-watersheds to the Popponesset Bay sub-embayments ranged from 0.76 kg/day in Pinquickset Cove to 39.99 kg/day in the Mashpee River. The sub-watershed loads affecting the Bay ranged from 0.422 mg/L (milligrams of nitrogen per liter) in Popponesset Bay to 0.958 /L in mg the Mashpee River.

Table 2.2 Embayment Waters within the Popponesset Bay Watershed on the 2006 Integrated List

NAME	SEGMENT ID	DESCRIPTION	SIZE	POLLUTANT LISTED
Mashpee River (9662775)	MA96-24_2006	Quinaquisset Avenue to mouth at Shoestring Bay (formerly to mouth at Popponesset Bay), Mashpee.	0.09 sq mi	- Nutrients - Pathogens
Popponesset Bay (96918)	MA96-40_2006	From line connecting Ryefield Point, Barnstable and Punkhorn Point, Mashpee to inlet of Nantucket Sound (including Ockway Bay and Pinquickset Cove), Mashpee/Barnstable.	0.67 sq mi	- Nutrients
Popponesset Creek (9662800)	MA96-39_2006	All waters west of Popponesset Island (from Popponesset Island Road bridge at the north to a line extended from the southeastern most point of the island southerly to Popponesset Beach), Mashpee.	0.04 sq mi	- Pathogens
Shoestring Bay (96905)	MA96-08_2006	Quinaquisset Avenue to Popponesset Bay (line from Ryefield Point, Barnstable to Punkhorn Point, Mashpee, including Gooseberry Island), Barnstable/Mashpee.	0.31 sq mi	- Nutrients - Pathogens

2.2.4 Eelgrass Habitat

The first aerial photographic surveys of Popponesset Bay in 1951 documented eelgrass beds with significant coverage within the central bay and the upper bay near the mouth of Shoestring Bay (Table 2.3, Figure 2.4) suggesting these waters were of high quality without the impacts associated with nitrogen loading (Charles Costello, MassDEP Eelgrass Mapping Program). However, follow-up MassDEP field surveys in 1995 and in 2001 identified an embayment system in decline with the loss of eelgrass throughout the Popponesset Bay System. Today, the nitrogen loads affecting the embayment system have been sufficient to promote the growth of microalgal blooms during the summer months, as suggested by their high chlorophyll a levels (exceeding 20 μ/L). As stated earlier, these algal blooms are of sufficient density in the water column to shade the floor of the seabed. Without adequate sunlight, the eelgrass beds are unable to sustain their energy requirements via photosynthesis and eventually perish. For the same reason, these ecosystems cannot be reestablished as habitat and spawning ground, nursery, and protective cover for commercially important finfish, and shellfish. The eelgrass beds that were first identified in 1951 have since been replaced by macro algae, which are undesirable because they do not provide the high quality habitat for fish and invertebrates. In the most severe cases, this habitat degradation has the potential of leading to periodic fish kills, unpleasant odors and scums, and near loss of the benthic community and/or presence of only the most stress-tolerant species of benthic animals.

The complete loss of eelgrass beds throughout the Popponesset Bay Watershed makes the presence or loss of eelgrass a difficult parameter to use in evaluating water quality within the sub-embayments. Yet, infaunal study results indicate an ecosystem capable of supporting diverse healthy communities in the region nearest the tidal inlet, with most of the system having an infaunal habitat that is significantly impaired under present N loading conditions.

Table 2.3 Popponesset Bay's Eelgrass Acreage (Past and Present)

Embayment	1951 (Acres)	1995 (Acres)	2006 Acres)	Percent Loss
Popponesset Main Bay	85.41	0	0	100
Shoestring Bay	10.64	0	0	100
Mashpee River	0.83	0	0	100
Ockway Bay	0	0	0	
Pinquicket Cove	0	0	0	
TOTAL	96.88	0	0	100

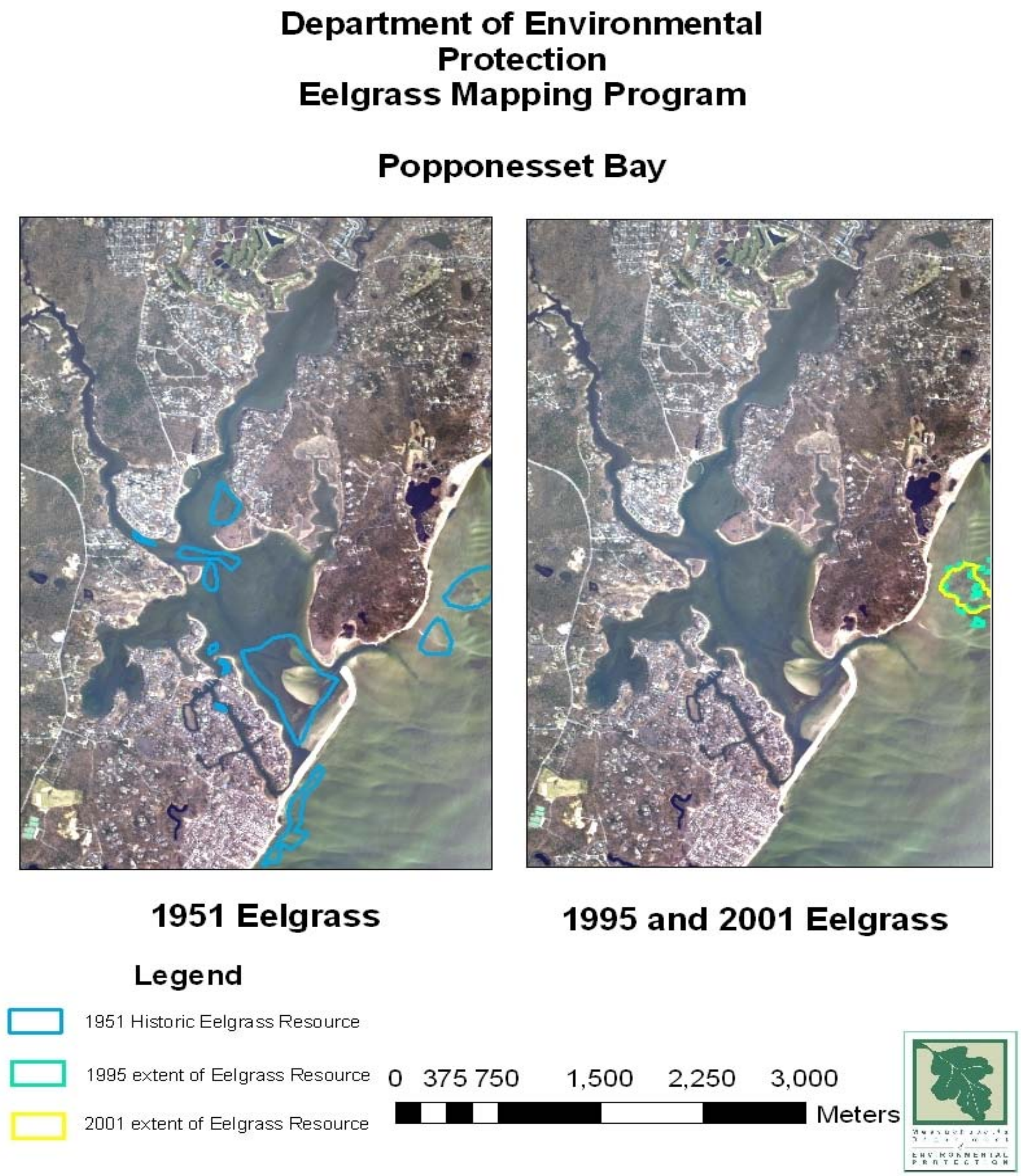


Figure 2.4 Pleasant North Orthophoto of Past (1951) and Present (2001) Distribution of Eelgrass Beds - 1951 historical imagery not field checked (Source: MassDEP, Charles Costello, MassDEP Eelgrass Mapping Program)

2.2.5 Sentinel Station

The sentinel station was located within the upper region of the central basin to Popponesset Bay at the mouth of Shoestring Bay (Figure 2.3), and the uppermost eelgrass bed detected in the 1951 data. Under present loading conditions the sentinel station supports a measured nitrogen level at mid-ebb tide of 0.581 mg/L TN and a tidally corrected average concentration of 0.451 mg/L TN. This location was selected as a sentinel station because: (1) it was the upper extent of the eelgrass coverage in 1951, (2) restoration of nitrogen conditions supportive of eelgrass at this location will necessarily result in even higher quality conditions throughout the whole of the central basin, and (3) restoration of nitrogen concentrations at this site should result in conditions similar to 1951 within Shoestring and Ockway Bays. Shoestring Bay and Ockway Bay should then be supportive of high quality habitat for benthic animal (Infaunal) communities. Based upon current conditions, the infaunal analysis (Chapter VII, MEP Technical Report) coupled with the nitrogen data (measured and modeled), indicated that nitrogen levels on the order of 0.4 to 0.5 mg/L TN are supportive of high quality infaunal habitat within the Popponesset Bay System.

2.2.6 Watershed Land use

Land use in the watershed, as identified in the MEP technical report, is predominantly residential and public municipal and public/private open space, with one third of the lots with single-family homes (Figure 2.5).

Vegetative cover consists primarily of a mixture pine, oak and beech with limited agricultural production, confined to cranberry production.

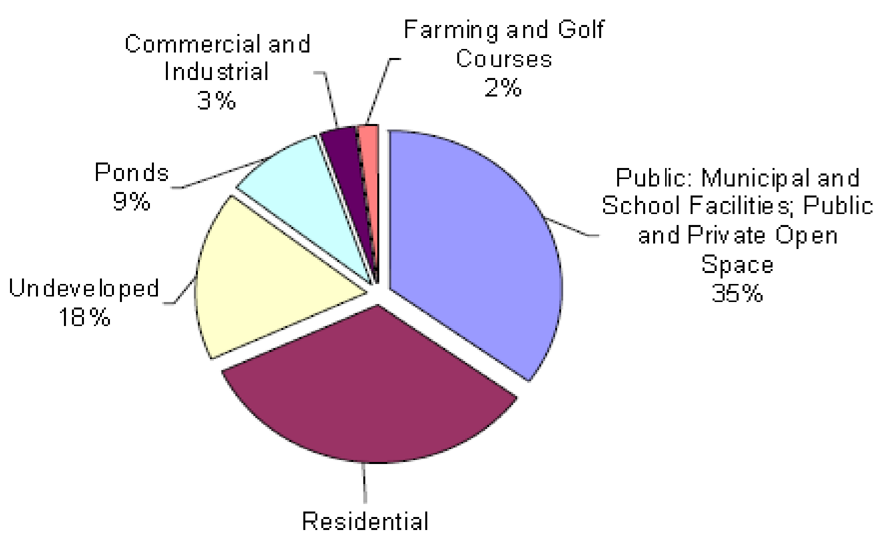


Figure 2.5 Popponesset Watershed Land Uses

2.3 Sources of Nitrogen

There are many sources of nitrogen affecting the estuarine water quality and each has an impact. Table 2.4 and Figures 2.6a-c identify three major sources: atmospheric deposition, sediment regeneration (benthic flux) and contributions from both natural and anthropogenic sources in the watershed. Figures 2.6a-c illustrates three levels of understanding. Figure 2.6a represents the percentage of all the loads affecting water quality from all estuarine and watershed sources. Figure 2.6b identifies the percentage of the sources of nitrogen from the watershed and Figure 2.6c represents the percentage of those watershed sources that can be controlled by wastewater management practices. As presented in Figure 2.6a, loads contributed to the estuary are not always from the watershed; there is also atmospheric deposition and nitrogen regeneration from the biological decay of biomass deposited in the embayment's sediment layer (benthic flux). When considering the nitrogen contributions affecting the coastal waters from the watershed, on-site septic system loads represent 63 percent of the overall load and 84 percent of the controllable load.

Because the contributions of nitrogen from atmospheric deposition and those recycled from the sediment are not loads that can be controlled by any watershed-based management strategy, we are left with the watershed loads (Figure 2.6b) that can be controlled (Figure 2.6c).

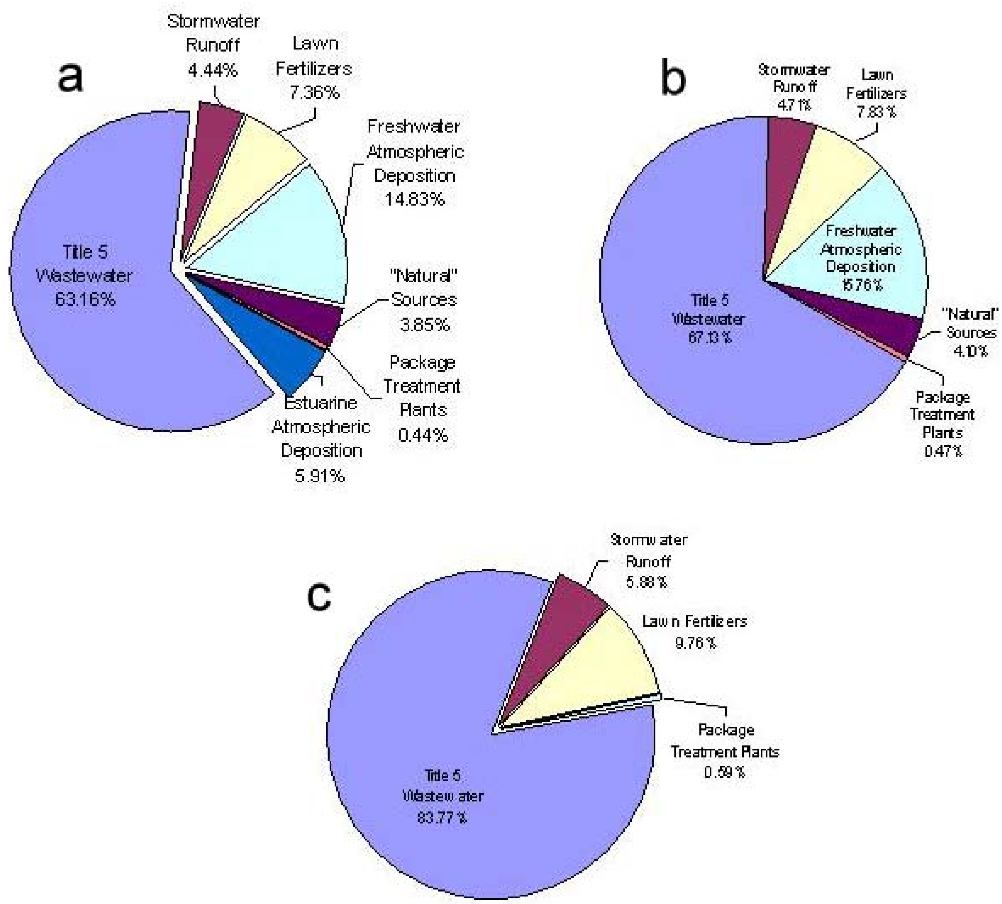


Figure 2.6a-c. Popponesset Bays Estuary and Watershed Nitrogen Sources of (a) Combined Unattenuated Nitrogen Loads, (b) Watershed Sources of Unattenuated Loads and (c) Combined Watershed Loads that are Controllable. Source: SMAST Popponesset Bays Technical Report by Howes, B. et. al, 2004, Chapter 4, Table IV-4.

Table 2.4 Sources of Nitrogen Loads to the Popponesset Bay Embayment and Watershed

Source	Kg N/Year
Title 5 Wastewater	32300
Stormwater Runoff	2268
Fertilizers (lawns and agriculture)	3765
Fresh Water Surface – Atmospheric Deposition	7584
"Natural" Sources	1971
Package Treatment Plants	227
Estuarine Surface Water - Atmospheric Deposition	3022.2
Total Unattenuated Load	51137.2

Clearly, the reduction of the septic load, representing 84 percent of the controllable (stormwater, fertilizers, package treatment plants) watershed load is the source that must be controlled and also the subject of this and other management plans. The use of the Linked Model for the reduction of nitrogen takes into account the contributions from atmospheric and benthic flux, as it simulates the affect of any plan for a septic load reduction that addresses the threshold concentration that must be achieved at the sentinel location in the bay.

2.3.1 Wastewater Treatment Plants and Onsite Systems

Approximately ninety seven percent of the 3509 residential and commercial parcels are served by onsite systems and the remaining three percent are served by package treatment plants. The number of these systems was not determined as the number of public water service connections and those on private wells within the watershed, not the number of parcels, was the most valuable in determining the watershed's nitrogen loads (SMAST confirmed that 90% of the residential metered water use was returned to the watershed as wastewater). Since a service connection to a condominium frequently includes multiple units, each with its own service connection, it was decided not to estimate the number of onsite Title 5 systems. However, it is clear - the majority of the parcels are served by on-site septic systems with nearly 2000 dwellings/homes served by small package treatment plants (Sterns and Wheeler, 2007. Town of Mashpee, Popponesset Bay Needs Assessment Report)

Fewer than four percent of all on-site systems in the watershed are nitrogen-reducing systems, which have been approved for a 19 or 25-mg/Liter nitrogen effluent limit.

The deployment of I/A nitrogen-reducing onsite systems creates a public support challenge to long-term nitrogen reduction plans, for two reasons. First, they cannot be the long-term solution for wastewater treatment. Although they are more effective than conventional septic systems in reducing nitrogen loads by 25-45%, (from 30-35 mg/L to 19 mg/L), most affected estuaries require nitrogen reductions in the range of 60-80%. Secondly, these I/A systems are expensive to install and operate, and can fail unless managed carefully. In addition, if an owner is required to spend a substantial sum to install one of these systems, they may understandably be reluctant to spend more money for sewering or other higher-level technology because the I/A system contributed to the solution.

To help educate the public about the environmental impact of nitrogen reducing systems and to instill the importance of taking collective action, the Pilot Team requested the School of Marine Science and Technology to model the impact of sewering all properties in the watershed with innovative/alternative Title 5 systems (IA) under build out conditions (i.e., all existing plus any projected development under current zoning). The results of the model runs confirmed the belief that the IA systems alone would not achieve the required reductions to restore and sustain water quality at the TMDL threshold concentration.

The five privately owned wastewater treatment facilities in the Popponesset watershed, designed for large commercial or residential developments, currently contribute less than 1% (0.47 %) of the total yearly controllable load to Popponesset Bay (Figure 2.6b). The unused capacity of the five privately owned treatment plants provides an opportunity, following future wastewater management planning, to evaluate the potential of upgrading and extending their use to adjoining neighborhoods with Title 5 septic systems given their design flow, and their relatively high nitrogen discharge limit (three of the four plants with a nitrate concentration limit of 10 mg/L, and one without a limit).

However, wastewater flows from residential (whether they fail or comply with code requirements) and small commercial developments (less than 10,000 gpd) represent the lion's share (84 percent) of the controllable load. Through the CWMP process, towns will need to consider the technical, managerial, financial, and inter-municipal coordination issues related to the selection of a wastewater treatment option for town and/or watershed wide utilization and benefit.

It is likely, following the completion and approval of a MassDEP approved` CWMP, that a variety of wastewater treatment options will be implemented, singularly or in combination. It is highly possible that the excess capacity of existing treatment plants will be insufficient to treat the required additional flows. New plants may be needed, while existing plants may be incorporated within a proposed overall watershed-wide system. In addition, comprehensive wastewater management planning and implementation may require additional nitrogen reduction technologies to lower the nitrate discharges of existing plants below the current 10 mg/l permit limit; thus maximizing on costs and benefits, flows, and nitrate reductions at Title 5 septic system locations.

2.3.2 Treatment Plant Discharge Locations

Identifying a suitable location to construct a treatment facility and to discharge its treated effluent is an increasingly difficult issue on Cape Cod and other MEP communities, given the space limitations at preferred sites where housing densities favor a treatment plant and the prohibition under the Massachusetts Ocean Sanctuaries Act ((M.G.L. c132A section 15-16) from siting new surface water discharges in Nantucket Sound or to Massachusetts Bay (see: http://www.mass.gov/legis/laws/mgl/132a-15.htm). The Act prescribes that these locations "… shall be protected from any exploitation, development, or activity that would significantly alter or otherwise endanger the ecology or the appearance of the ocean, the seabed, or subsoil thereof, or the Cape Cod National Seashore". As a result, future wastewater treatment plants on Cape Cod and the Islands will continue to discharge treated wastewater flows to the subsurface environment as permitted as a MassDEP groundwater discharge permit.

Yet, this limitation may be challenged in view of recent studies that have identified low level, part per trillion, of pharmaceuticals and personal care products (some of which are endocrine disruptors) in drinking water, presumably entering groundwater from wastewater effluent from Title 5 septic systems and/or state permitted wastewater treatment plants. In view of these and other public health concerns, there may a public outcry against future groundwater discharges as they may pose a public health nuisance and a reexamination of the limitations imposed by the Ocean Sanctuaries Act. Under MGL c132a § 16A, there are "…cases where the prohibition in section fifteen against discharges of municipal wastes into the ocean sanctuaries may not further the purposes of the act, such discharges may be allowed; provided, however, that a suitable quality of effluent is achieved to protect the appearance, ecology, and marine resources of the sanctuary; and, provided further that the department, in its discretion, upon application, grants a variance from the prohibitions of said section fifteen for the proposed discharges, subject to the provisions of sections sixteen B to sixteen F, inclusive".

High growth rate MEP communities may find limitations in the siting of these wastewater treatment discharges if the only lands available for discharge are within Zones of Contribution (Zone IIs) to public supply wells and coastal watershed to nitrogen sensitive estuaries. While the Groundwater Regulations (310 CMR 5.00; see: http://www.mass.gov/dep/water/laws/regulati.htm#gwp) provide adequate public health protection safeguards for the siting of state permitted wastewater treatment plants within Zone IIs, towns are also exploring increasingly creative options for wastewater disposal in coastal watersheds to nitrogen sensitive embayments). The Town of Mashpee considered in its CWMP the possibility of locating wastewater discharge outside the Popponesset Bay watershed to an area where groundwater would flow directly to Nantucket Sound rather than the nitrogen sensitive Popponesset Bay estuary. The Popponesset Team evaluated the potential of relocating a wastewater disposal site near New Sudbury's wastewater treatment facility. Unfortunately, the proposed site could handle a maximum of 500,000 gpd, compared to the need for disposing 3-4 million gpd.

2.3.3 Stormwater

Sources of water quality impairment also exist from stormwater runoff off buildings, roads, and driveways. Collectively they contribute 4.4% of the overall load (Figure 2.6a), stormwater runoff represents 5.8% (Figure 2.6c) of the watershed-wide unattenuated controllable load, slightly more in sub-watersheds with a greater percentage of developed land. Stormwater and fertilizer management are closely related, because lawn fertilizers frequently wash off lawns during rainfall events and becomes part of the stormwater runoff load.

The EPA NPDES Phase II stormwater-permitting program, which regulates stormwater discharges, requires certain towns to have general permits that commit them to carry out a variety of Best Management Practices (BMPs). Examples from the towns' Annual Reports include detection of illicit discharges, treatment of discharges, changes in local management practices such as street sweeping and collection of hazardous wastes, public education, and local bylaw changes to prohibit dumping into stormwater drains. Reducing fertilizer use will also attenuate nitrogen loading from stormwater.

MassDEP's revised Stormwater Policies and Guidance at should be consulted for recommended best management practices for controlling stormwater impacts to surface waters. (see: http://www.mass.gov/dep/water/laws/policies.htm#storm)

. SMAST has also identified the following BMPs that warrant further investigation for nitrogen removal:

- Vegetated swales
- Retention ponds
- Constructed wetlands
- Sand/organic filters
- Infiltration basins/trenches

2.3.4 Fertilizer Use

As an importance source of nitrogen, fertilizer use contributes 7.3% of the overall load contributed all sources, it accounts for 10% of the unattenuated, locally controllable load of nitrogen in the watershed (Figure 2.6). Ten percent of the controllable loads are from the following sources:

- Lawns and town parks: 76% of the unattenuated fertilizer load is contributed from residential lawns and town parks. This represents 7.6% of the total unattenuated controllable load with residential lawns supplying most of the load. The MEP Technical Report estimates that only half of all residences fertilize, and at rates well below the recommendations by lawn care companies. As more seasonal homes become year-round, there is potential for a significant increase nitrogen loads from lawn fertilizing.

- Farmland and cranberry bogs: MEP Technical Report data files list approximately 29 acres as agricultural land, or 0.42% of the total Popponesset Watershed acreage and most in cranberry production.
- Golf courses (Willowbend, and portions of Quashnet Valley and Cotuit Highlands): Golf courses contribute 24% of the unattenuated fertilizer load, equal to 2.4% of the total unattenuated controllable load. Loads from golf courses are a larger share of the load in the sub-watersheds where they are located - primarily in the Upper and Lower Mashpee River, Quaker Run, Santuit River, and Shoestring Bay.

2.4 Demographics

2.4.1 Land Use Change

During the past 58 years, land use development pressures within the Popponesset Watershed have been dramatic with a substantial loss of undeveloped land (Table 2.5, Figures 2.7 – 2.8). Coincident with this change was a substantial increase in the number of year round single-family homes and the conversion of seasonal to year-round residences. These changes are also reflected in the loss of undeveloped forest land for suburban use.

Table 2.5 List of acreage of developed and undeveloped land in the Popponesset Watershed from 1951 to 1999 (MassDEP GIS)

YEAR	Developed Acreage	Undeveloped Acreage	Total Acreage*	Percent Developed	Percent Undeveloped	TOTAL_PCT
1951	533	11097	11630	5%	95%	100%
1971	1317	10306	11623	11%	89%	100%
1985	2535	9088	11623	22%	78%	100%
1999	4628	6994	11622	40%	60%	100%

* Exclusive of acreage from lakes and ponds
+ Refer to Figure 2.8 for landuse codes for these two categories of land use.

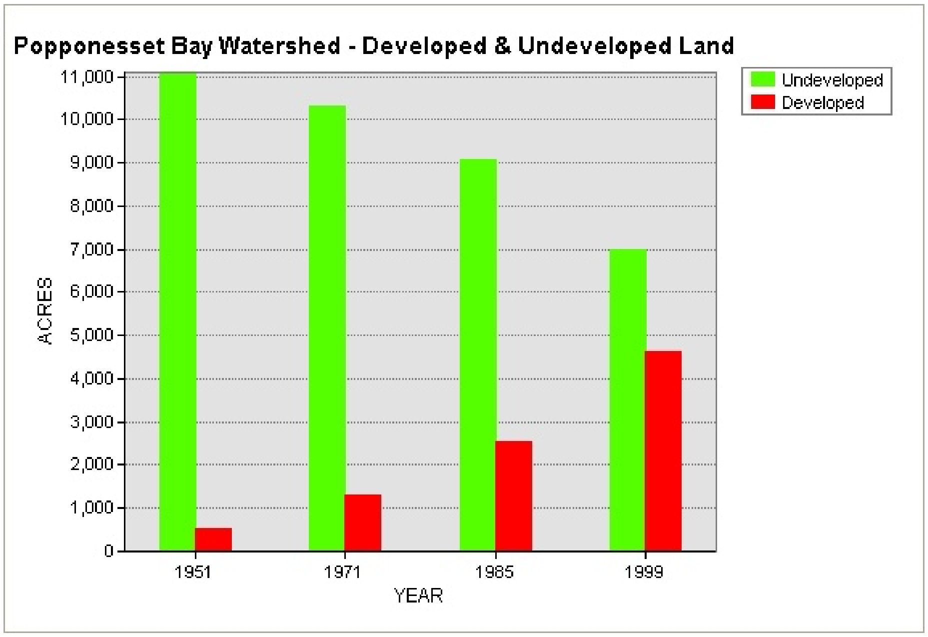


Figure 2.7 Graph of acreage of developed and undeveloped land in the Popponesset Watershed from 1951 to 1999 (MassDEP GIS)

As expected, water quality problems associated with this transformation are primarily from on-site wastewater treatment systems, and to a lesser extent from stormwater runoff – and the use of lawn

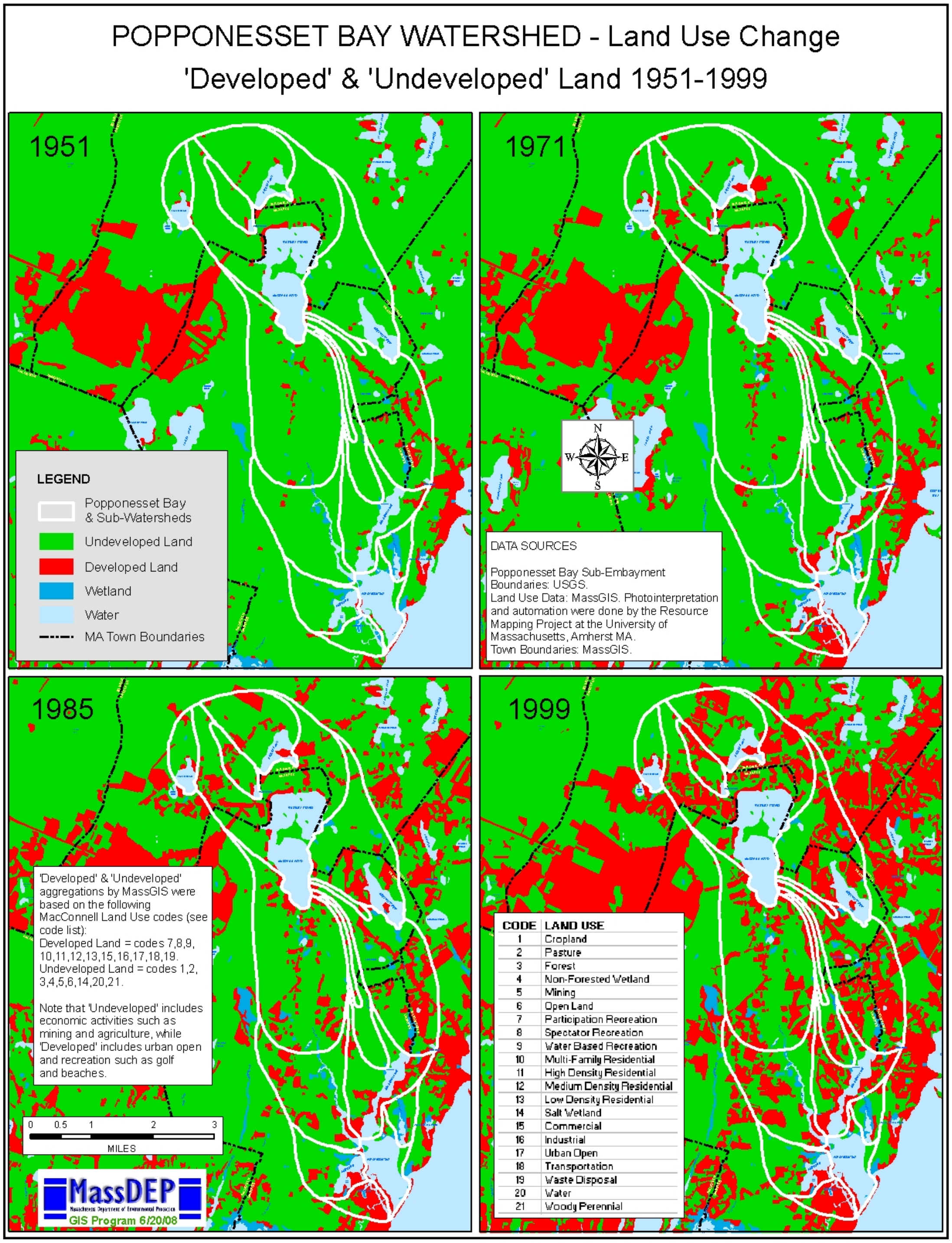


Figure 2.8 Map of acreage *of developed and undeveloped land in the Popponesset Watershed from 1951 to 1999* **(**MassDEP GIS**)**

fertilizers. The installation of onsite Title 5 systems in these unsewered areas of the watershed has greatly affected the water quality of the sub-embayments from the subsurface discharge of wastewater effluent from these on-site systems. These discharges enter the groundwater system and eventually affect surface water bodies down gradient as it flows seaward. In the sandy soils of Cape Cod, the movement of nitrogen in groundwater is unimpeded, flowing at the same rate as groundwater at an average rate of one foot per day.

2.4.2 Population Growth

US Census data indicate a population growth rate that has consumed an increasingly greater percentage of the open space in the three towns since the 1950s (Figures 2.7 and 2.8 and Table 2.5), with the Town of Mashpee taking the lead in population growth for all time intervals (1950 to 2000; 1990 to 2000; and 2000 to 2006) (Figure 2.9 and 2.10). The highest rate of growth occurred from 1950 to 2000 with a 2856 percent increase, followed by Sandwich at 737 percent and Barnstable at 356 percent. While these rates reflect town wide patterns, they also reflect increases in residential development and wastewater discharges within the watershed from on-site water septic systems, mostly in the town of Mashpee representing 64 percent of the land area within the Popponesset Bay watershed. Dramatic declines in water quality, and the quality of the estuarine habitats, throughout Cape Cod, have paralleled its population growth. Intuitively, it can be argued that the nutrient load increases affecting the groundwater system of the Popponesset Watershed is directly related to the increase in subsurface wastewater disposal systems that accompanied both land development and population growth.

Table2.6. Percent Population Growth from 1950 to 1990, for the Popponesset Watershed Towns

Town	**1950 – 1960**	1950-1970	1950-1980	1950-1990	1950-2000	1990 – 2000	1990 - 2006
Barnstable	28.5	89.3	194.8	291	356	16.7	15.6
Mashpee	98	194	745	1700	2856	64.2	81.9
Sandwich	-14	117	261	541	737	30.6	32.4
TOTAL	20	85	196	235	443	61.6	64

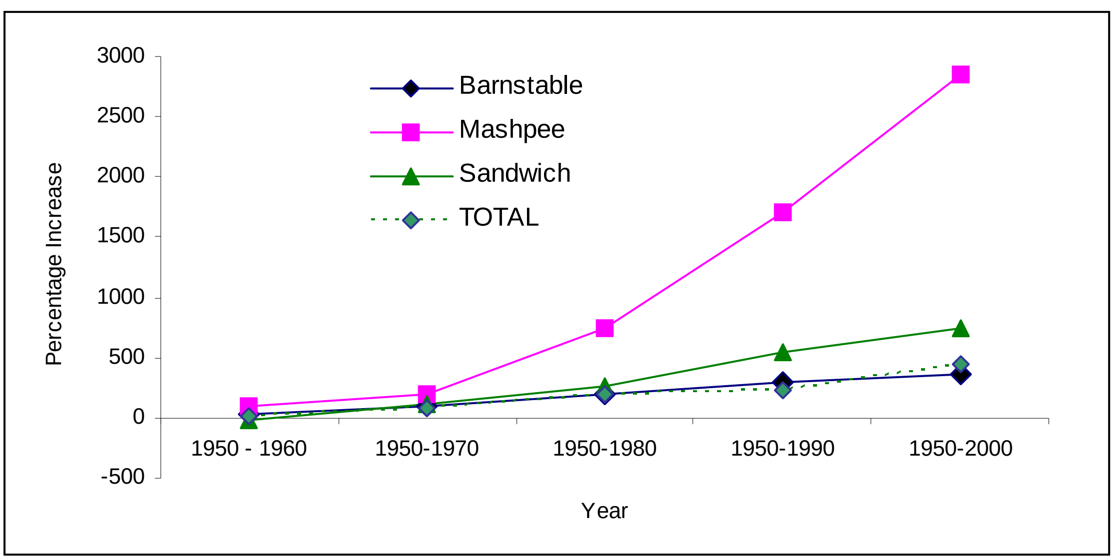


Figure 2.9 Percent population increase since 1950 for Popponesset Watershed Towns

The population of Mashpee and Barnstable, as with all of Cape Cod, has increased markedly since 1950. http://www.capecodcommission.org/data/trends98.htm#population). Of the three towns, Mashpee underwent the greatest percentage increase (Table 2.5, Figures 2.9) following the 1983 federal court settlement of the land claim by the Wampanoag Indian tribe to reclaim the entire town as tribal land. This suit clouded Mashpee's property titles for nearly a decade. When the court ruled that the Wampanoag Indian tribe had no legal grounds because it was not federally recognized, the town's landowners were no longer constrained in developing or selling their properties. As a result, land development and population growth in Mashpee, representing 64 percent (Table 2.1) of the land area within the watershed, "led not only Cape towns but the entire State and probably all of New England, more than doubling (+113%) from 3,700 in 1980 to 7,884 in 1990." The town of Barnstable, the largest of Cape Cod's 15 communities, added the most new residents (10,051) from 1980 to 1990 (Figure 2.10). A Cape Cod Commission study (Cape Trends Report, 1998) reported that the town of Barnstable, from 1990 to 1996, gained another 2,750l new residents for a 7% increase to 43,699; the second highest of the 351 Massachusetts cities and towns (following Franklin's 4,569). The Town of Sandwich also saw a substantial increase in growth for the same six-year period for a 16% increase from 15,489 to 17,916 - the highest percentage gain increase among Cape towns.

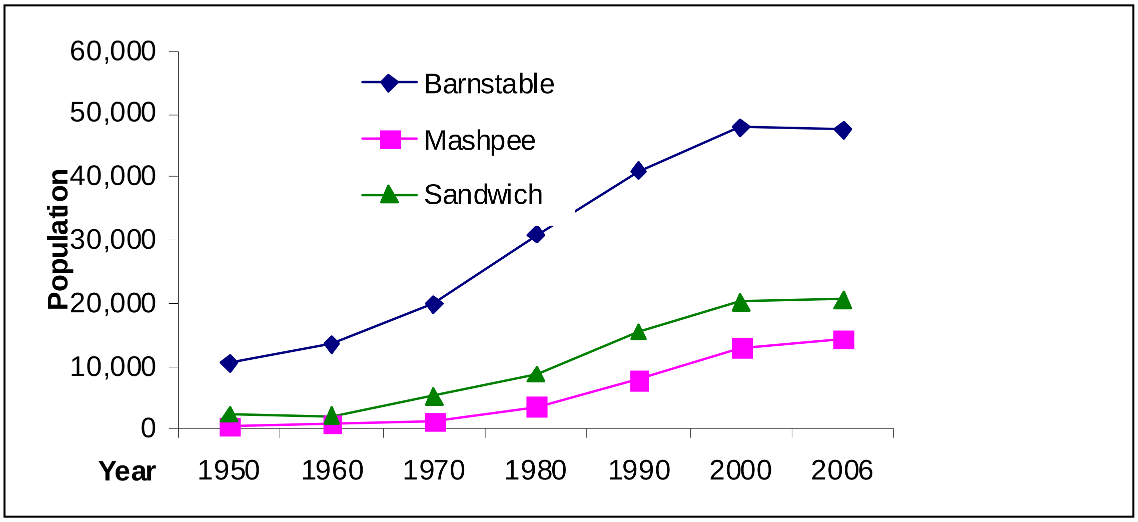


Figure 2.10 Population growth since 1950 for the Popponesset Watershed Towns

The MEP Popponesset Bay Technical Report (2004) estimated the population of the Popponesset watershed at 14,000 with the average household size at 2.54. Since the completion of the MEP Technical report (2004), basing its estimates on 2001 data, the three towns continued to grow. For example, the Town of Mashpee's estimated 2006 population (US Census) outpaced both Sandwich and Barnstable with an increase of 10.79 percent (12,946 to 14,343) from 2001 to 2006 period; while Sandwich grew a modest 1.3 percent (20,238 to 20,508) and Barnstable having a –0.92 percent (from 47,821 to 47,380) (Table 2.5, Figure 2.9).

The significance of these statistics is clear; in the absence of municipal sewering, Title 5 on-site septic systems continue to serve new households with ever increasing nitrogen loads to this estuary beyond the 2004 MEP Technical Report estimates; meaning that the MEP Technical and EPA approved TMDL estimates of loads and reductions will need to take into account the estimates the MEP Technical Report has identified as inevitable and provides an estimate of these future loads under the buildout conditions provided by current zoning for each of the towns sharing this watershed.

2.4.3 Population Density

US Census population density (Figure 2.11), reported as persons per square mile, are also helpful in assessing land use development patterns as they define where the wastewater burden affecting the Popponesset Bay embayments are the greatest. Overall, this increase in population density within the Popponesset Bay watershed is expected to contribute greatly to the nitrogen loads affecting this embayment system.

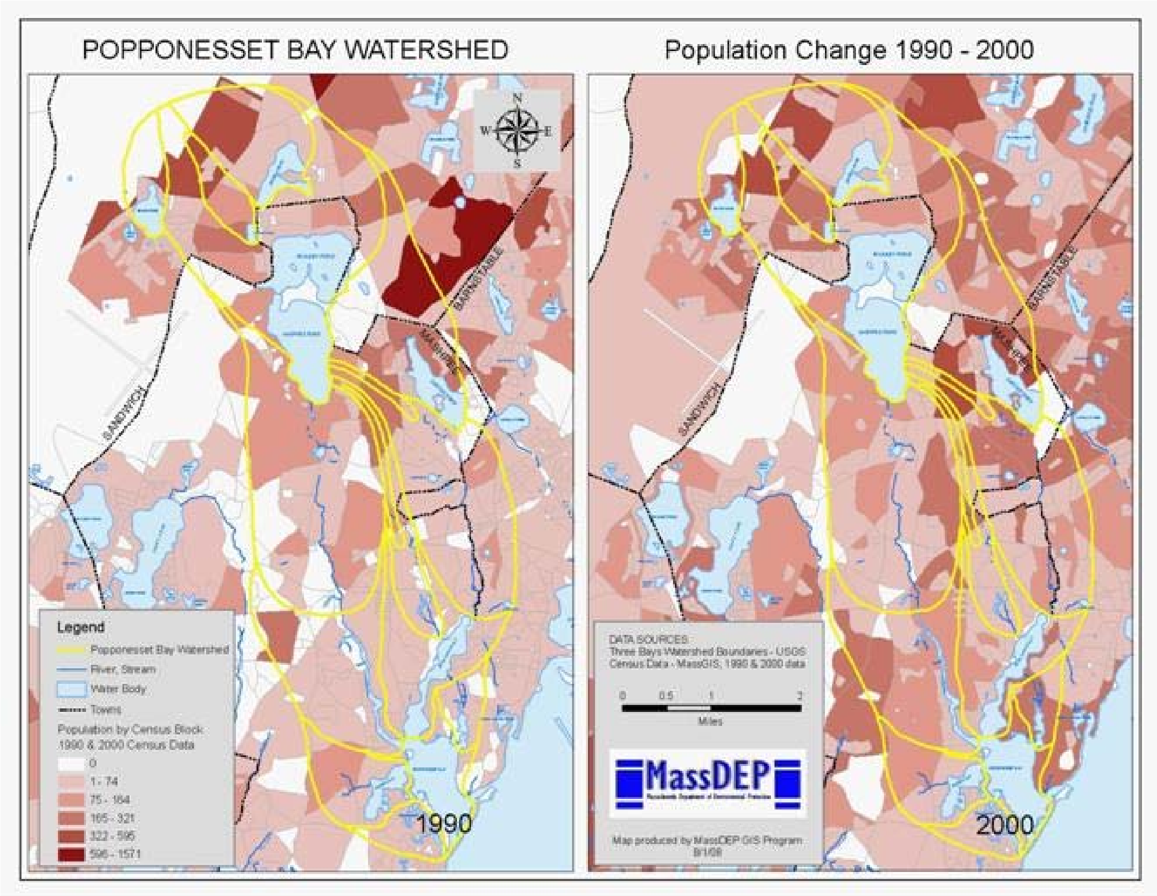


Figure 2.11 Change in population density in the Popponesset Watershed from 1990 to 2000 (US Census)

2.5 Building the Popponesset Bay Watershed Team

This Pilot Project relied on a team of key local officials and citizens, with Mashpee as the lead town with support from the Cape Cod Commission, MassDEP, and SMAST (Table 2.7). In addition to the three town leads, membership included staff from Mashpee's Offices of Health, Conservation, Shellfish, and Waterways, and the Planning Board. The key players from Barnstable were from the Department of Public Works and the Growth Management Department. Sandwich's key player was the Health Agent (appointed position). Key players from environmental organizations included the Mashpee Environmental Coalition, Three Bays Preservation, Cotuit Waders, and Nantucket Sound Keeper. The title of these individuals is less important than their ability to collaborate regionally and to connect with other key staff and elected officials from their towns. Staff from SMAST attended in the early stages of the Pilot and to develop and discuss modeling scenarios. Consulting engineers and Barnstable County staff also attended occasionally or as requested.

Prior to the first meeting, MassDEP met with key officials in each town to explain the project and requested that each town agree in writing to provide the time of local officials and staff needed to move the process along. The groundwork for initiating and engaging inter-municipal collaboration within the Popponesset Bay Watershed had already been established by Mashpee's pre-existing watershed wide wastewater management planning, involving participation of town officials from the towns of Sandwich and Barnstable as Citizens Advisory Committee (CAC) members.

Table 2.7 Popponesset Bay Watershed Pilot Team

Name	Affiliation
Baker, Edward	Mashpee Environmental Coalition
Barker, Claire	MassDEP, Project Manager (former)
Counsell, Lindsey	Three Bays Preservation\Barnstable Growth Management Department (former)
Buschinfeldt, Evelyn	Mashpee Environmental Coalition
Dudley, Brian	MassDEP, MEP Coordinator, Hyannis
Eichner, Eduard	Cape Cod Commission – Water Scientist
Ells, Mark	Town of Barnstable, DPW Director
Fudala, Tom	Town of Mashpee, Planning Department and Sewer Commission
Hanks, Jim	Town of Mashpee, Chair Waterways Commission (former)
Kane, Beverly	Town of Mashpee, Chair Planning Board
Mason, David	Town of Sandwich, Board of Health/Water Quality Advisory Committee
Molloy, Ken	Cotuit Waders
Rockwell, Heather	Nantucket Sound Keeper
Saad, Dale	Town of Barnstable, DPW Special Projects Manager
Solbo, Steve	Town of Mashpee, Conservation Agent (former)
Weissman, Mark	Massachusetts Marine Fisheries Commission
York, Rick	Town of Mashpee, Shellfish Constable
Zoto, George	MassDEP, Project Manager, Hyannis

2.5.1 Team Meetings

The Pilot Project Team met, on average, once a month over five years from 2003 to 2008 and covered a broad range of issues affecting the restoration of water quality to the Popponesset Bay system.

Team meetings focused on:

- In-depth understanding of the Technical Report and use of the Linked Model.
- Review of the nitrogen reduction scenario described in the MEP Technical Report (Chapter VIII.3) to help develop alternate nitrogen reduction scenarios to be evaluated through additional modeling.
- Three model runs by SMAST proposed by the team to determine if the alternate reductions achieve the threshold concentration at the sentinel station in Popponesset Bay by testing the results of non-sewering alternatives such as on-site septic denitrification systems, and natural attenuation in old cranberry bogs.
- Allocation of load reduction responsibilities between towns.
- Discussion of local and state wastewater management and regulatory issues.
- Providing outreach to the local community on results of case studies and interact with other case study communities on nitrogen reduction issues of mutual interest.

Initially, staff from SMAST attended to introduce the MEP approach for data collection, quantification of nitrogen loads, and the environmental "what if" inputs to the MEP Linked Model for use in calculating outcomes for reducing watershed nitrogen loads and/or its allocation by town.

Town staff from other offices typically attended meetings that addressed technical and policy related issues in their area of expertise and responsibility; however, as the focus shifted to the broader management and multi-town issues, they were less likely to attend. A key success factor was their staying abreast of the project through meeting notes, and becoming involved at times when a topic was important to their work.

The impact of having one town take the lead on implementation may be mixed: on one hand, it was clear that Mashpee will move ahead with planning and implementation regardless of the planning by the towns Sandwich and Barnstable. At the same time, the towns with a minority stake may not participate because their focus may be on the watersheds within their town borders where they are the lead or because town officials and citizens may not fully understand or agree with the nitrogen loads they are responsible for reducing. For example, with only 25% share of the watershed and none of it fronting on Popponesset Bay or the Mashpee or Santuit Rivers, it may be a hard sell to convince Sandwich taxpayers about their responsibility for reducing their contributions to the Popponesset Watershed. They may view that they would derive no benefits from such a costly action as their coastal frontage is to the north, on Cape Cod Bay, where its residents have easy access to the town beaches and boat landings.

During its first two years, the Popponesset Bay Pilot Project Team spent a great deal of its time becoming familiar with the fundamentals of wastewater pollution and wastewater management options, including:

- Wastewater Loads: Treatment Plants and Onsite Systems
- Pollution Prevention: Fertilizer Management, Water Reuse and Conservation, and Stormwater Management
- Enhanced Natural Attenuation
- Other: Aquaculture, Weed Harvesting, Dredging, and Inlet Alteration

These options led to more detailed discussions concerning the reduction of each town's nitrogen load as a shared responsibility as outlined below and presented as SMAST Technical Memos describing the outcome of scenario runs for the nitrogen reductions proposed by the Team. The technical issues discussed, and presented in this report, also include:

- Wastewater Nitrogen Load Allocations
- Nitrogen Load Reduction Scenarios
- SMAST Technical Memoranda
- Water Quality Monitoring
- Monitoring Requirements and Data

2.6 Assessing and Characterizing the Problem

As part of the MEP, the health of the estuarine habitat was evaluated for use in establishing the water-quality threshold to maintain or improve habitat quality. Nitrogen threshold levels are defined by the MEP as "the average water column concentration of nitrogen that will support the habitat quality being sought".

On April 10, 2006, the SMAST and the Massachusetts Department of Environmental Protection determined that the total nitrogen threshold concentration of 0.38 N L^{-1} is supportive for the restoration of eelgrass habitat in Popponesset Bay at its designated sentinel station at the upper portion of Popponesset Bay and the mouth of Shoestring Bay (Howes et al., 2006; MassDEP TMDL, 2006). This threshold concentration stems from field assessments of water quality where eelgrass beds exist. These beds are located in: (1) Stage Harbor, Chatham where tidal water also exchanges with Nantucket Sound and for which a MEP target has already been set; (2) Waquoit Bay where a vestigial eelgrass bed exists near the inlet (measured TN of 0.395 mg N L^{-1}, tidally corrected <0.38 mg N L^{-1}); (3) West Falmouth Harbor and (4) other Cape Cod systems with similar nitrogen dynamics.

The nitrogen load reductions identified to achieve the 0.38 mg N L^{-1} threshold concentration at the sentinel station in the estuary from each of the five sub-watersheds ranged from 1 to 26 kg/day. These load reductions for each sub-watershed were the basis for discussion – to identify an equitable approach to reduce the contributing loads from each town's portion of the watershed. The Popponesset TMDL report (http://www.mass.gov/dep/water/resources/popptmdl.pdf) should be consulted for a more detailed presentation.

2.6.1 Enhanced Natural Attenuation: Potential of the Santuit Pond Preserve

A number of sites in the Popponesset Bay watershed were studied to evaluate the potential of utilizing enhanced natural attenuation to reduce the nitrogen loads in groundwater. The Team focused on an area of abandoned cranberry bogs in the Santuit Pond Preserve; an area bordering the Towns of Mashpee and Barnstable and jointly owned and managed by the two towns and the Commonwealth's Division of Fish and Game (Figure 2.12).

The Preserve's 293 acres of forest and open land, with upland habitat, wetlands, vernal pools, and portions of Santuit Pond and the Santuit River in addition to abandoned cranberry bogs appeared to have significant potential for nitrogen attenuation. The area of interest includes eight or more abandoned cranberry bogs on the west side of the Santuit River, ranging from less than 1 to several acres. Two of the bogs abut the Santuit River. Except for the two western-most bogs, all have standing water at some time during the year; the amount of periodic flooding and/or standing water seems to have increased in the years since the bogs were abandoned.

Two proposals were discussed by the Team and modeled to determine the potential of reducing the nitrogen loads by natural attenuation. These enhancements for improving natural attenuation included:

- Deepening of abandoned bogs into open water ponds.
- Converting abandoned cranberry bogs to freshwater wetlands, thereby increasing the sinuosity of streams and the opportunity for denitrification by stream and wetlands sediments.
- Modifying the historic flow regime to maximize the ponding that takes place in many abandoned cranberry bogs, thereby increasing retention times.

In the fall of 2005, staff from MassDEP, Barnstable, Mashpee, and Three Bays Preservation walked the area to evaluate site conditions and its suitability for the needed changes. During this period, SMAST, Three Bays Preservation, and the Town of Barnstable began sampling flow rates and direction, nitrogen transfers among bogs, and the nitrogen discharge from the bogs to the river.

Utilizing the results of their field studies, the Pilot Team requested SMAST's assistance to analyze the potential of natural attenuation from two proposed alterations: 1) deepening three bogs to create ponds enhancing their function and increasing the watershed area from which nitrogen would be drawn; and 2) managing the flow regime through a greater number of bogs. In brief, three bog/ponds (Bogs A, B, C) within the Santuit Pond Preserve would be "converted" to fresh ponds to enhance natural attenuation (Figure 2.12). The two eastern bogs are permanently flooded. It was discovered that deepening the three bogs was estimated to promote a very small gain in natural attenuation because of the small amount of flow to the Santuit River (~ 5 % during winter and ~ 25% during summer of (2005-2006) captured by the up gradient bogs system. Based on the limited data set, these limited flows regimes appeared to have a nitrogen attenuation of > 160 kg N/yr west of the bogs and between 200-240 kg N/yr when the adjacent bogs are also removing additional nitrogen. However, when the flows and pond/wetland management are optimized by increasing the attenuation efficiency to 40-50%, SMAST estimated a conservative increase in N removal of 320-400 kg N/yr and still higher rates of removal when flooding promoted natural plant species uptake.

SMAST suggested that natural attenuation could be enhanced by increasing the flow regime. Based on the flow and natural attenuation calculations in one bog during a 3-month period, SMAST estimated a 40 – 50 % increase in natural attenuation efficiency with the potential of attenuating 400-600 kg N annually by optimizing flow between the ponds and maintaining flooded conditions. This suggests that natural attenuation has the potential of removing 500 kg N/year and the avoided cost of sewering 90-95 homes, based on an estimated 5.3 kg/year (2.1 kg/N/yr per person x 2.54 persons per household in the watershed) of nitrogen discharged per house.

At best, SMAST's Linked Model calculations were estimates. More data collection is required for use in considering the true nitrogen attenuation potential of the Santuit Pond Preserve bogs. Based on SMAST's recommendations, the Popponesset Team will continue to collect additional data to quantify the true potential of the nitrogen attenuation option of the bogs. Additional modeling will be needed when field study results become available on the composition and depth of the bottom sediments; the underlying aquifer materials, including year long groundwater and surface water flow patterns through this system; and quantitative evaluations of nitrogen removals under managed conditions for the watershed acreage and flow regimes; especially during the critical summer months. The Management Committee has approved a survey of the site to determine historic flow patterns among bogs, and SMAST is continuing its monitoring in order to obtain 12 months of data on flows and current attenuation. Future steps require hydro-geological studies to evaluate the capacity for flooding or deepening the bogs to increase the retention and contact time with the bog muck sediments to enhance the potential of nitrogen removal by natural attenuation. Local officials will also need to evaluate the desirability of having open water in each bog.

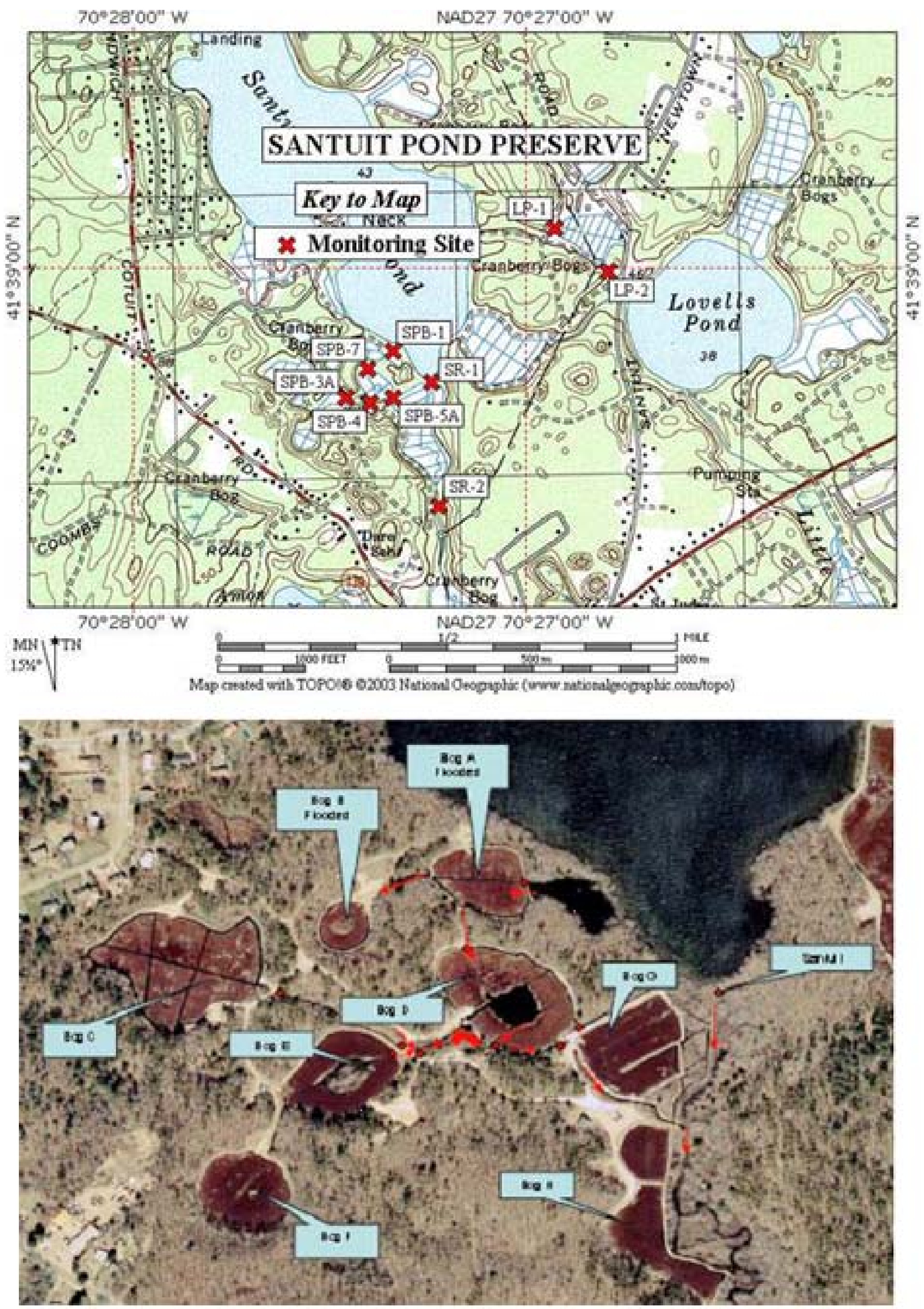


Figure 2.12 Santuit Pond Preserve - Map and aerial view of monitoring sites, courtesy of Three Bays Preservation, Inc.

In addition to potentially avoiding the cost of sewering a significant number of houses in this area, restoration of the bogs will likely increase habitat diversity, by replacing a monoculture with native vegetation, and make the area more attractive the public for passive recreation.

In response to this interest in natural attenuation as an alternative to wastewater treatment, MassDEP initiated a scientific and regulatory review to govern this strategy. Massachusetts has some of the nation's most protective wetland regulations: the Wetlands Protection Act Regulations at 310 CMR 10. The Wetlands Protection Act does have room for projects that impact a wetland resource but provides for overall resource enhancement. Existing examples are fish ladders and management of invasive species in ponds. MassDEP's Guidance for Aquatic Plant Management in Lakes & Ponds describes the Department's approach to resource enhancement projects (see: http://www.mass.gov/dep/water/laws/alkguide.pdf).

Extending this approach to projects that enhance natural attenuation of nitrogen will require balancing the various interests of the Wetlands Protection Act. For example, alterations could negatively impact a freshwater wetland (e.g., destruction of bordering wetlands vegetation) in order to improve water quality in a downstream estuary.

The following key elements of the Guidance are already clear.

1. Enhanced natural attenuation cannot be the only method used for attenuating nitrogen in a watershed, but must be considered in conjunction with other strategies that also includes wastewater treatment, stormwater and fertilizer controls, and water conservation. Enhanced natural attenuation may be useful in combination with other attenuation alternatives such as wastewater treatment and stormwater management.
2. Alterations in different resource types will raise different issues with the Wetlands Protection Act. The following list ranks protected resources in increasing order of concern:
    a) Creation of wetlands constructed from uplands raise the fewest concerns
    b) Wetlands systems which have already been altered, e.g., recently abandoned cranberry bogs
    c) Resources which have been altered, but are long-standing (e.g., long-abandoned cranberry bogs)
    d) Conversion of one type of resource to a different type
    e) Alteration of pristine, well-functioning wetlands would raise the most concerns. Salt marshes are of particular concern because of their limited scope and high ecological value. Although the Wetlands Protection Act does not have a resource enhancement exemption for coastal habitat, projects that enhance the salt marsh are allowed under 310 CMR 10.32 (5).
3. Alterations must demonstrate a positive impact on the interests of the Wetlands Protection Act. Strong cases for alteration will have the following characteristics:
    a) Large number of wetland functions supported (e.g., pollution prevention, fish habitat, preventing erosion and siltation)
    b) Documentation of negative impacts and efforts to minimize the impact
    c) High percentage of nitrogen attenuation
    d) Ability to predict and measure attenuation.

The first step in MassDEP regulatory evaluation of Enhanced Natural Attenuation has been a search of scientific literature to document the effectiveness of natural attenuation of nitrogen in different types of wetlands and waterbodies, describe optimal designs and site modifications to enhance existing natural attenuation rates, and establish data needs for review of natural attenuation project proposals. The Pilot Project funded this work by the Woods Hole Group of Falmouth, MA. See Appendix H for the Executive Summary of this report or download one or more of the project deliverables listed under "Natural

Attenuation of Nitrogen in Wetlands and Waterbodies" at
http://www.mass.gov/dep/water/resources/coastalr.htm

A detailed discussion of the Santuit Pond Preserve study is presented as scenario 3 in the SMAST document "*Popponesset Bay: Results Pilots Modeling Scenarios –Final*" dated May 2, 2006, with final the revision dated June 15, 2006 (Appendix I).

2.6.2 Aquaculture: Shellfish Growing and Harvesting on the Lower Mashpee River

In 2004, the Mashpee's Shellfish Constable initiated a pilot project to determine the potential for growing oysters to attenuate nitrogen in the lower Mashpee River (Appendix Q)

The Shellfish Constable's working hypothesis is based on the belief that the addition of significant numbers of oyster seed to this embayment system via shellfish aquaculture can have an important role in reducing the nitrogen loads affecting the estuary, through nitrogen attenuation and denitrification in sediments under the shellfish growing area. Because these animals are filter feeders, it is believed that their increased presence can have a significant role to reducing the system's total nitrogen through the assimilation of the phytoplankton into shellfish biomass. Once fully implemented, it is believed that such a project has the potential of removing several hundred kilograms of nitrogen annually, or close to 10% of the amount needed to meet the threshold nitrogen targets. The additional community benefits include the opportunity to educate the public on estuarine restoration and harvesting local oysters.

However, given the Pilot Project Team status and the uncertainties inherent in a biological process, the Local Team agreed that the potential nitrogen reductions from shellfish aquaculture should not be written into a restoration plan.

2.6.3 Harvesting Aquatic Vegetation on the Mashpee River

Several years ago, the Mashpee Wampanoag Tribe proposed to harvest and compost aquatic vegetation on the Mashpee River, with a process used in the Florida Everglades. The Waterways Commission is investigating this option, and more information may be available in the future, following the conclusion of this study. Note that vegetation harvesting raises a large number of technical and regulatory issues. Its potential to disturb the river bottom habitat would also need to be evaluated.

2.6.4 Dredging and Flushing Improvements

The shoreline hydrodynamics along Nantucket Sound is dynamic and heavily impacted by tides, ocean currents, and storms. Openings to the Sound naturally migrate or close. As a result, most Cape communities, including Mashpee through its Waterways Commission, have active dredging programs to maintain and improve existing navigation channels to the town's waterways. Dredging of the inlet to improve flushing of the Bay with each tidal cycle was also investigated by the Pilot Team; an effort led by the Chair of Mashpee's Waterways Commission.

The Popponesset MEP Technical Report (Chapter IX pp. 129-135) documented negligible or negative impacts affecting nitrogen concentrations from the dredging of the Mashpee River and the 1916 channel in Popponesset Bay (see: http://www.oceanscience.net/estuaries/Popponesset.htm).

The Technical Report recommends that the main inlet between the Bay and Nantucket Sound be maintained at its existing cross-section. However, the Mashpee Waterways Commission is exploring other options for dredging with the goal of reducing nitrogen levels through improved flushing while improving navigation at the same time.

2.7 Exploring Implementation Options

2.7.1 Comprehensive Water Resources Management Plans

An important measure of success for this Pilot Project is the usefulness of its results in subsequent local comprehensive planning. The Pilot provided more general modeling than would be done in comprehensive planning, but screened out a wastewater treatment option (denitrifying onsite systems) and raised the potential for an innovative reduction alternative (enhanced natural attenuation in wetlands). However, this discussion of the Pilot's findings and recommendations are much less detailed than that provided in comprehensive planning, particularly for towns such as Mashpee already engaged in a parallel planning track.

The Pilot focused in later meetings on issues of governance, management and allocation outside the typical scope of comprehensive planning. Ideally, results of these discussions will inform the towns on the way forward on non-technical aspects of restoring Popponesset Bay. In order for the Pilot to benefit local comprehensive planning, it will also be important for members of the Pilot Team to stay involved, either through the Community Advisory Committee or through liaison with the Town Planning Office/Sewer Commission in Mashpee, and the Barnstable and Sandwich officials with planning responsibility.

A watershed-wide nitrogen management plan is the ideal option for coordinated planning and implementation. It might be structured in several ways:

- A watershed-based Plan written specifically for a group of towns.
- One document that pulls together relevant information from plans of several towns.
- One town's plan that addresses watershed-wide issues and contains input from other towns in the watershed (the current Mashpee CWMP approach).

Although shared planning is easiest for towns, all starting their planning at the same time, most MEP towns are at different stages of planning. In these cases, coordination is even more important. Through the Pilot Project, Mashpee, Sandwich, and Barnstable have taken several of the suggestions below made by MassDEP:

- Begin talking together early in the process, by jointly reviewing the MEP Technical Reports and TMDL, discussing shared concerns, and even submitting joint comments on the Technical Report. Discussions and decisions about cost-sharing can happen regardless of whether towns are in the formal planning process
- Schedule inter-municipal briefings on the MEP and Technical Reports.
- Discuss nitrogen attenuation options and request model runs based on input from all towns.
- Coordinate formal planning and construction schedules where possible, or at least share information on individual plans.
- When formal planning begins, appoint Community Advisory Committee (CAC) members from other towns that share the estuary, as Mashpee has done.
- Create a joint written record of mutual decisions and a schedule of key points down the road at which coordination will be needed.
- For towns planning to include a number of estuaries in a town-wide plan, pursue implementation in watersheds solely within their town boundaries and hold off on final decisions in shared watersheds.

2.7.2 Inter-Municipal Collaboration

When towns collaborate to address the nitrogen reductions from their town, they are more likely to consider the time and cost savings involved in the planning and implementation of a watershed-wide

CWMP. MassDEP's primary recommendation is to make decisions on cost sharing separately from decisions on which restoration scenario is the most cost-effective and environmentally appropriate. The second decision should be based on watershed-wide criteria alone, while planning and cost-sharing decisions will be influenced, among other things, by intermunicipal dynamics and public acceptability.

Experience offers four additional guidelines on making cost-sharing decisions:

1. First agree on the criteria for choosing a cost sharing method.
2. Start with the nitrogen load contributions provided by MassDEP.
3. Consider a variety of cost-sharing methods.
4. Consider trading programs as part of cost sharing.

As a further response to this and similar requests concerning inter-municipal collaboration by other MEP communities, MassDEP prepared "Guidelines for Multi-Town Collaboration" (http://www.mass.gov/dep/water/resources/multi06.htm) for use by a town's leadership when deciding, among its many approaches, some choices for taking action and sharing responsibility for the management and cost for the restoration of water quality .

Concerning the selection of treatment options and the best locations, as defined by the MEP Linked model "what if" scenario model runs, municipal collaboration is more likely to acknowledge the limitations of natural attenuation when the proposed sites for sewering are closest to the estuary where the impacts on water quality are the greatest. As many factors are at play in deciding where, how much, and how to reduce N loading, with some sub-watershed locations more cost-effective than others, the team decided that this issue is strictly a local decision that must be decided by the leadership of each community.

2.8 Allocating Wastewater Nitrogen Loads

2.8.1 Unattenuated and Attenuated Loads

Figure 2.13 illustrates the nitrogen reductions that are possible from natural attenuation. The town of Sandwich's headwater discharge of 10,585 kilograms/year of unattenuated nitrogen, furthest from the shores of the Popponesset embayment system, is biologically reduced to 2,886 kilograms per year by the time this groundwater discharge reaches the estuary as an attenuated load. In contrast, the unattenuated load discharges from the towns of Mashpee and Barnstable, with discharges closest to the estuary, have a significantly limited capacity for the reduction by natural attenuation. As a result, the Town of Mashpee is the largest contributor of attenuated nitrogen to Popponesset Bay at 65 percent, followed by Sandwich at 22 percent and Barnstable at 13 percent.

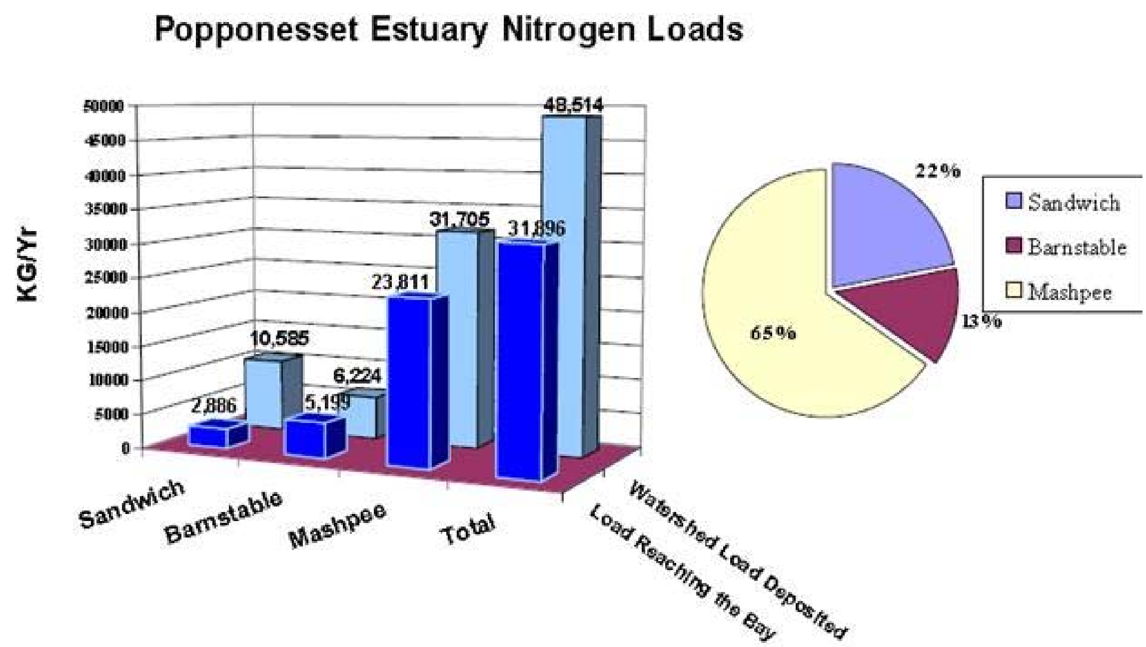


Figure 2.13 Unattenuated nitrogen load deposited in the watershed and attenuated nitrogen load reaching the Bay from each watershed town

2.8.2 Controllable and Uncontrollable Loads

Readers of MEP Technical reports have been introduced to three categories of discharged loads: those that are controllable and those that are uncontrollable, as well as those that are the most practical to control as part of a wastewater management plan. There are distinctions. An example of an uncontrollable load is atmospheric deposition of nitrogen resulting from power plant emissions and other combustion sources that affect water quality. Another uncontrollable load is the regeneration of nitrogen occurring in the sediments of the estuary from benthic flux (the decay of the plant and animal detritus deposited from the water column and from those living in this ecosystem). Since these loads are uncontrollable, they are considered inputs to the model and not a component of the watershed load. In other words, when calculating the maximum load that must be removed from the watershed or embayment, uncontrollable loads have to be handled separately and additional reductions are needed in the watershed to offset the gains from uncontrollable sources.

As defined in the MEP, the controllable sources of nitrogen consist of discharges from on-site septic systems, wastewater treatment plants, stormwater runoff, and fertilizer use (agriculture, lawns/turf). However, it is understandable why the MEP technical report relies heavily on the removal of septic loads of nitrogen throughout the various sub basins of the watershed since septic system discharges of nitrogen represent 63 percent of the nitrogen from all sources and more than 84 percent of the controllable sources (Figure 2.6 and Figure 2.13).

The nitrogen load reductions discussed at Team meetings focused on the controllable septic loads (excluding atmospheric deposition, benthic flux, runoff, or fertilizer loading), as defined in Table VIII-1 of the Popponesset MEP Technical Report Chapter VIII (Critical Nutrient Threshold Determination, see:

http://www.oceanscience.net/estuaries/Popponesset.htm). The septic loads were calculated from drinking water use statistics compiled by the Mashpee Water District for the 1997 to1999 period, the Cotuit[1] Water District for 1998 – 2000, and the Town of Sandwich Water Department for 1998 – 2000.

The nitrogen loads that affect the estuary, as presented in the MEP Technical Reports, are those that have been microbiologically decayed to nitrogen gas through denitrification (attenuated loads) vs. those loads discharged directly to the ground and not yet denitrified (unattenuated loads). When all is said and done, it's the attenuated load that the estuary "sees". Groundwater discharges in close proximity to the estuary have a limited capacity for natural attenuation and frequently, depending on proximity to the estuary, affects water quality directly as an unattenuated load. For example, the Town of Sandwich, the furthest away from Popponesset Bay, has the greatest nitrogen reduction from natural attenuation than the Town of Mashpee (Figure 2.13).

Towns sharing a coastal watershed should agree on the criteria they would use for deciding the load reductions they would be responsible for in their CWMPs. This may involve a lengthy process for an understanding of the sources that can be controlled by sewering at the source of the discharge, the role of natural attenuation, and the apportionment of responsibility for reducing controllable loads from its turf. Also, where and how much of a reduction should be planned that addresses the attenuated load limit that each town should not exceed to affect the TMDL sentinel station concentration. As an example, the MEP technical report's scenario for restoring water quality to the sentinel station in the Bay relied on the reduction of septic load reductions as the controllable load because they by in large, represent over 80 percent of the controllable watershed load. As one of many scenarios, Figure 2.14 defines the nitrogen reduction scenario used by SMAST (MEP Technical Report for the Popponesset) that identifies the percent reduction in septic loads (sewering) required to achieve the sentinel threshold concentration in Popponesset Bay. As this figure demonstrates, 100 percent sewering of locations closest to the estuary where the loads are unattenuated and have the greatest impact to the estuary, achieved the target threshold concentration at the sentinel location. This is only one of several scenarios that could have been chosen. However, the scenario a town chooses in its CWMP will decide if it is the most cost effective and environmentally sound choice.

A complete presentation of the additional scenario runs the Pilot Project Team requested of SMAST can be found in Appendix L; including the questions asked by the Team and the answers conveyed by SMAST.

2.8.3 Putting It All Together

Deciding how to put these calculations to work in defining what each town within a watershed should do to reduce their share of the nitrogen load is a matter each town will decide, at some point. Keep in mind this exercise is somewhat hypothetical, relying on modeling to define the loads that should not be exceeded, when in fact, the criterion that will determine if compliance is met for TMDL compliance purposes will be the re-establishment of eelgrass or habitat for benthic animals.

With this said, there are controllable loads and those that are not. There are loads that undergo natural attenuation when the geography is advantageous for removing nitrogen and those that do not. As stated previously, there is also the issue of the unattenuated load when close proximity of a discharge to the bay is a factor in releasing the full effect of the load to the estuary. How should towns sharing a watershed decide what reductions are needed to restore nitrogen at the threshold concentration at the sentinel station, given the fact that the loads being discharged vary among towns and even within subwatersheds with a same town?

[1] Cotuit is a village in the Town of Barnstable

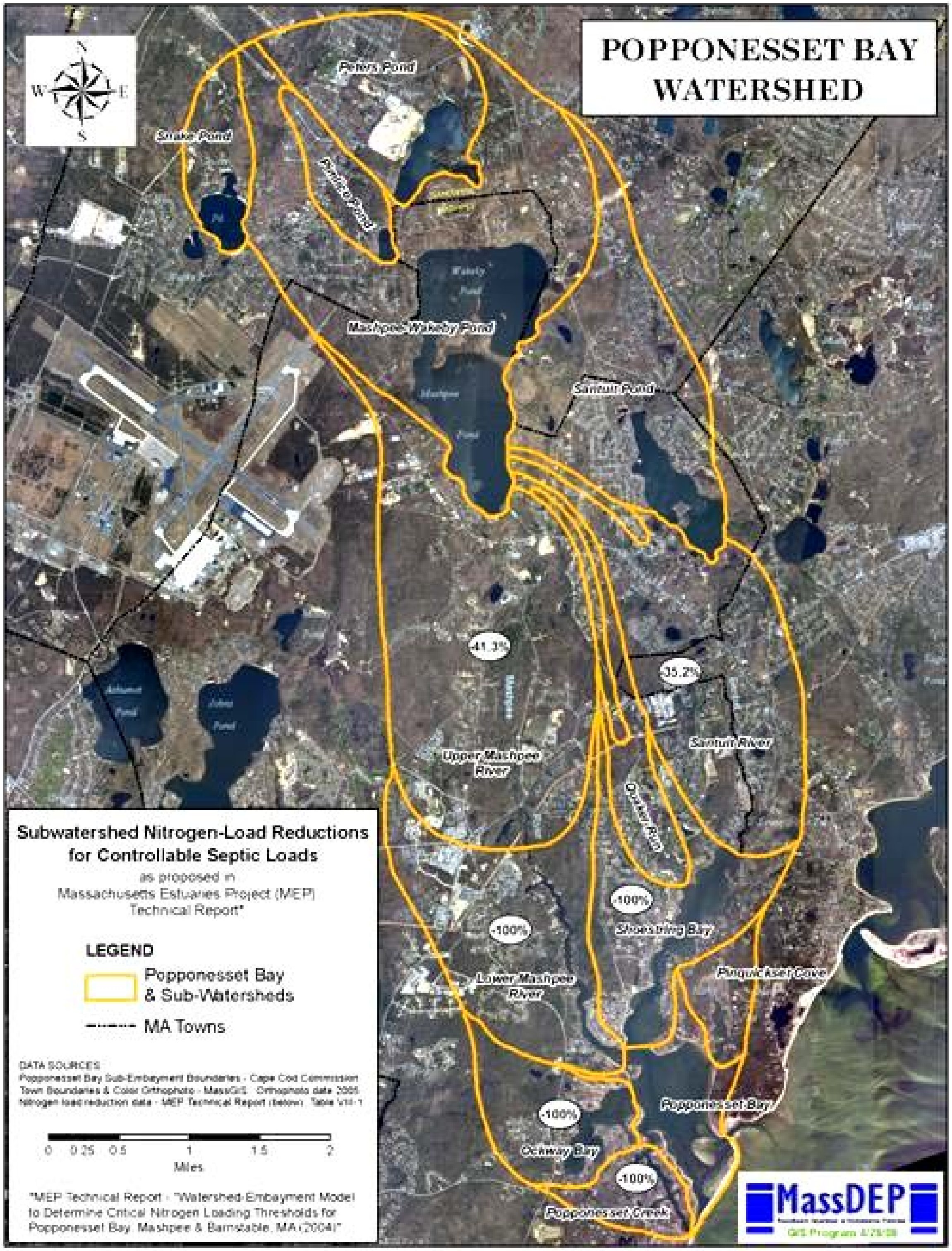


Figure 2.14 MEP Technical Report scenario with the percent reduction in septic loads needed in each subwatershed to restore water quality at the sentinel station
Source: Popponesset MEP Technical Report, Chapter VIII, Table VIII-2)

These were issues the Popponesset Team spent a great deal of time discussing. As will be reported, there are different points of view on what should be done. First, it should be understood that the MEP Technical and MassDEP TMDL reports are the basis for defining both subwatershed and watershed-wide nitrogen loads with little consideration concerning its town of origin. As a result, town-by-town nitrogen loads, attenuated and unattenuated, were not included. This however, was information the Team desired. Consequently, at the request of the Team, MassDEP calculated the controllable (septic, lawn fertilizers, wastewater treatment, and stormwater runoff) town-by-town unattenuated and attenuated loads, utilizing the following formula:

- Unattenuated present loads were based on parcel coverage, where parcels were assigned to a watershed based on which watershed 50 percent or more of the land is located, then the parcel loads were calculated from on-site wastewater systems, wastewater treatment plants, lawn fertilizer and natural systems.

- Impervious surface contributions (i.e. stormwater runoff) were estimated by applying the percentage of each town's area within the watershed to the overall impervious surface area load. These loads could not be calculated directly because town-specific data on road area were not incorporated in the original model.

- Surface water contributions were estimated both from the loads of freshwater bodies completely within each town's boundaries and, for water bodies shared by two or more towns, by apportioning the loads based on the percentage of the water body in each town.

- Estimates of attenuated loads are based on the MEP Technical Report methodology.

The outcome of MassDEP's calculation of town-specific unattenuated and attenuated loads from various sources (on-site septic systems, wastewater treatment facilities, fertilizers, stormwater runoff from impervious surfaces, direct atmospheric deposition to water surfaces, and recharge from natural areas) is presented in Table 2.8.

Table 2.8 Unattenuated and Attenuated Nitrogen Loads by Town

Town	Unattenuated N		Attenuated N	
	Kg/yr	% of Total	Kg/yr	% of Total
Sandwich	10,585	22	2,886	9.0
Barnstable	6,224	13	5,199	16.3
Mashpee	31,705	65	23,811	74.7
Total	48,514	100%	31,896	100%

The nitrogen loads presented in the MEP Technical and MassDEP TMDL reports are based on detailed, parcel-specific calculations for all parcels and portions thereof within the watershed.

This information, derived from the MEP nitrogen loading data and summarized in the Technical Report's "rainbow table" (Chapter 4, Table IV-5), served the Team in its discussion concerning the town-by-town assignment of responsibility where each town is allocated an N load for subtracting from its town boundaries. In conjunction with the watershed load limit provided in the TMDL, the town-by-town calculation of loads provided a limit that each town should also not exceed now or in the future as zoning permits at buildout. Table 2.8 defines the actual load reaching the embayment from each town under current (2000 – 2001 data) loading. As Table 2.8 suggests, the load defined in the MEP Technical Report will need to be updated, as the population for Mashpee which represents 64 percent of the watershed (Table 2.6) has continued to show a significant 17 percent increase in its population from 1990 to 2006 However, for TMDL purposes, the watershed controllable load shown in Table 2.9 (reprinted from the TMDL report) should not exceed 40.18 Kg/day for the watershed as a whole. The current "existing" controllable load (2000 – 2001 data) of 76.06 Kg/day must be reduced by 47.2 percent in order to achieve the threshold sentinel concentration for compliance with the TMDL. However, as shown in Table 2.9, the required reductions will not be the same for each of the affected subembayments.

As a result, please note, any plans for reducing loads must take into account the differences in each subembayment. However, these targeted subwatershed threshold loads as presented in Table 2.9 must be further reduced because they did not take into account the loads from atmospheric deposition and benthic flux. Table 2.11 (reprinted from TMDL report) accomplishes this final step by either increasing or decreasing the loads that must not be exceeded in each subembayment.

Table 2.9 Nitrogen loading rates from present controllable watershed sources, loading rates necessary to achieve target nitrogen concentrations, and the percent reduction needed to achieve the target

Popponesset Bay System Sub-embayments	Present controllable watershed load [1] (kg/day)	Target Threshold Watershed Load [2] (kg/day)	Percent watershed load reductions needed to achieve threshold loads
Mashpee River	34.15	16.17	52.7
Shoestring Bay	31.24	19.72	36.9
Ockway Bay	3.15	0.76	75.9
Pinquickset Cove	0.77	0.76	1.3
Popponesset Bay	6.75	2.77	59
	76.06	40.18	47.2

[1] Composed of combined fertilizer, runoff, WWTF effluent, and septic system loadings
[2] Target threshold watershed load is the load from the watershed needed to meet the embayment threshold N concentration of 0.38 mg/L identified above.

The critical element of this TMDL process is achieving the sub-embayment specific N concentrations presented in Table 2.11 that are necessary for the restoration and protection of water quality and eelgrass habitat within the Popponesset Bay sub-embayments. In order to achieve those target concentrations, N loading rates must be reduced throughout the Popponesset Bay Watershed. Table 2.11 lists target watershed threshold loads for each sub-embayment. If those threshold loads are achieved, the overall Popponesset Bay System will be protected.

This loading reduction scenario is one of many ways to achieve the target N concentrations. Towns are free to explore other loading reduction scenarios through additional modeling as part of the CWMP process.

Table 2.10 The Total Maximum Daily Loads (TMDL) for the Popponesset Bay System, represented as the sum of the calculated target thresholds loads (from controllable watershed sources), atmospheric deposition, and sediment sources (benthic flux).

Embayment System and Sub-embayments	Range of Average Observed System Nitrogen Concentration [1] (mg/L)	System Threshold Nitrogen Concentration (mg/L)
Popponesset Bay		0.38
Mashpee River	0.958-0.627[2]	
Shoestring Bay	0.690-0.520[2]	
Ockway Bay	0.677-0.536[2]	
Pinquickset Cove	0.527	
Popponesset Bay	0.485-0.422[2]	

[1]Target threshold watershed load is the load from the watershed needed to meet the embayment threshold concentrations identified in Table 2.11. The goal of this TMDL is to achieve the identified N threshold concentration in the identified sentinel system. The target load identified in this table represents one alternative loading scenario to achieve that goal but other scenarios may be possible and approvable as well.

[2] Projected sediment N loadings obtained by reducing the present loading rates (TMDL Report Table 3) proportional to proposed watershed load reductions and factoring in the existing and projected future concentrations of PON.

[3] Sum of target threshold watershed load, atmospheric deposition load, and benthic flux load.

Table 2.11 Observed nitrogen concentrations at present and calculated target threshold nitrogen concentrations derived for the Popponesset Bay Sub-embayments

Popponesset System Sub-embayments	Target Watershed Threshold Load [1] (kg/day)	Atmospheric Deposition (kg/day)	Benthic Flux [2] (kg/day)	/TMDL [3] (kg/day)
Mashpee River	16.2	0.7	9.4	**26**
Shoestring Bay	19.7	2.2	-8.7	**13**
Ockway Bay	0.8	1.1	1.1	**3**
Pinquickset Cove	0.8	0.3	-0.3	**1**
Popponesset Bay	2.8	4.0	-5.5	**1**

[1] calculated as the average of the separate yearly means of 1997-2003 data. Individual yearly means and standard deviations of the average are presented in MEP Tech Report (Howes, B. et. al., 2004) Tables A-1 Appendix A

[2] listed as a range since it was sampled as several segments (see MEP Tech Report (Howes, B. et al., 2004) Table A-1 Appendix A)

2.8.4 Allocating Loads a Watershed Scale

The Commonwealth's history of strong local home rule and municipal authority presented a challenge for allocating town-by-town, watershed wide load reductions. With this understood, the team decided that any allocation of responsibility should conform to the following principals.

- Environmental Benefit
  - Make progress toward restoring estuarine habitat and water quality standards
  - Measure progress and use adaptive management as required
- Equity
  - Water quality restoration considers all significant sources of nitrogen
  - All who contribute to the problem and/or benefit from the solutions help pay
  - All towns, regional entities, and other interested parties are included in the decision-making process
- Efficiency
  - Those closest to the problem decide the most cost-effective solution
  - Local, regional, and state stakeholders coordinate on solutions without duplicating efforts
  - Possibilities exist for voluntary solutions and trading
  - State regulations and policies are not unnecessary barriers to solutions

The allocation of nitrogen reductions, as a fair and shared responsibility, was the most contentious issue for the Local Team; affected by the different ideas of fairness, and the differing interpretations of the MEP Linked modeling results. After much discussion, Team members settled on the following formula.

- The allocation of responsibility for reducing nitrogen is based on a reduction from all existing 2000/2001 nitrogen sources within the Popponesset Bay watershed (septic systems, wastewater treatment, fertilizers, impervious surface discharges, freshwater bodies (atmospheric inputs), and natural surfaces (fields and forests)). These loads do not include direct atmospheric deposition (onto the sub-embayment surface) or benthic flux inputs. These loads, as of 2000/2001, were run through the MEP Linked model which determined that a 49.2 percent reduction from 2001 levels would be required to meet the Popponesset nitrogen threshold at the sentinel location in the Bay. The remaining 50.8 percent of the 2001 load constitutes the allowable load for each town.
- All towns should reduce nitrogen by the same percentage of their unattenuated load.
- Require each town or inter-municipal reduction plan to achieve the nitrogen threshold at the sentinel station which, in turn, will to restore the currently impaired eelgrass and benthic infaunal habitats throughout the estuarine system.

From a local perspective, this approach reflects a sense of fairness and burden sharing: since each town contributes to the problem, each town should contribute to its restoration. Furthermore, the voters of a community may resist contributing to the solution unless they know that each town is equally engaged. For these reasons, this team chose the unattenuated nitrogen loads by town, as it reflected the actual loads discharged to the ground that contributed to the problem (albeit less because of natural attenuation).

This approach was deemed "fair" and simple to explain to decision makers and the public, and not dependent on N modeling scenarios.

Model runs would determine the single lowest possible percentage reduction of nitrogen in all sub-watersheds that would meet the sentinel and secondary nitrogen targets. A similar approach, presented in the Popponesset MEP Technical Report, resulted in a watershed-wide reduction of 45.2%, so the concept of an equal percent reduction by town had the possibility of working. The only significant caveat was that both of these analyses were based on greater percent reductions in selected subwatersheds and lower reductions in others.

Determining the watershed-wide average reduction each town would be responsible for reducing required multiple MEP Linked Model runs with an anticipated reduction higher than the 47 percent average reduction in the TMDL and the SMAST June 15, 2006 Tech Memo (Appendix I). The goal was to determine if a constant watershed nitrogen load reduction (evenly applied to all watershed sources) could be developed and meet the nitrogen threshold at the sentinel site for Popponesset Bay. SMAST was requested to determine what reduction was needed to meet the TMDL target for the watershed. The result of the MEP Linked model was a 49.2 percent reduction of the watershed load (Figure 15) [refer to Appendix L (Howes, B. et al., MEP Technical Memo, April 6, 2007). It was determined that if each town made a 49.2 percentage reduction of its 2001 unattenuated nitrogen load, it would provide the optimal reduction of all sources of nitrogen within Popponesset Bay. When achieved, the nitrogen threshold at the sentinel location would be attained. The model estimated that the sentinel station would be lowered to 0.352 mg TN/L, below the 0.372 mg TN/L threshold developed in the MEP Technical Report and well below the TMDL N Threshold of 0.380 mg TN/L. The infauna "check" stations were also well within the acceptable range (0.4-0.5 mg TN/L). It was determined that the nitrogen reductions produced by this scenario should be sufficient to restore the eelgrass and infaunal animal habitats throughout this estuarine system.

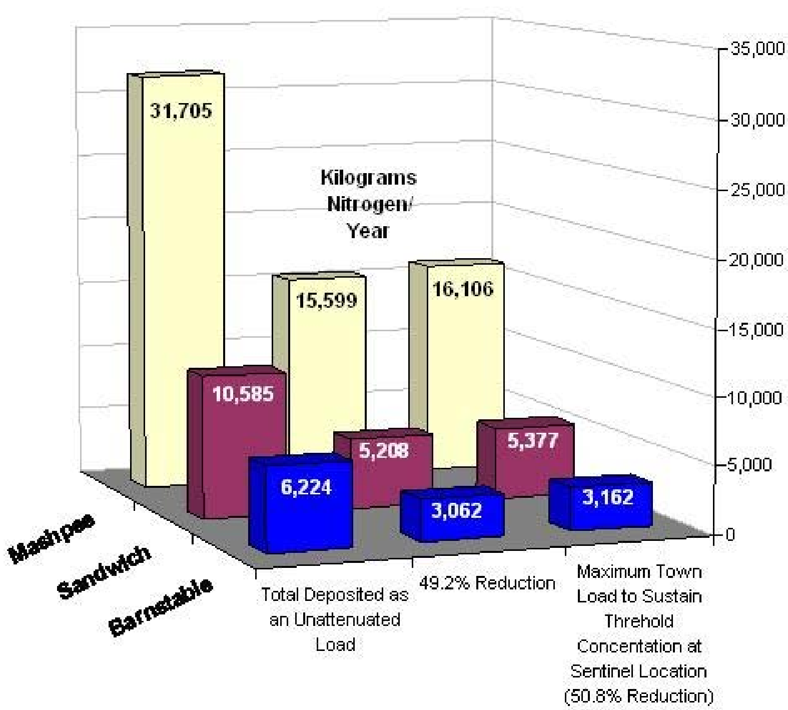


Figure 2.15 Equal Percentage for each town of Nitrogen Reduction Deposited as an Unattenuated Load to the Popponesset Watershed*

*Based on 2001 MEP Popponesset Technical Report loads. A portion of the nitrogen load from Sandwich is contributed by the Massachusetts Military Reservation (369 acres ~ 10.8% within the Town of Sandwich and 2.74% of the land area within the Popponesset Watershed).

As a result, the Team chose to apply the "fair share" 49.2 percentage system-wide reduction from each town's total contribution of nitrogen to the watershed (Figure 2.15). In effect, this resulted in a nitrogen load target for each town of 50.8 percent of its 2000/2001 load. In essence, this 50.8 percent remainder sets in place a permanent target that must not be exceeded in the future to restore and sustain water quality at the sentinel station in the Bay. All of the discussions on allotting responsibility for sharing and the reduction calculations were originally based on attenuated loads at the sentinel location (less benthic and estuary surface, as they were in the hydraulic model). The common thread was whatever arrives at the bay is what impacts it, not what goes into the ground. Both the town percent share calculations and the reduction calculation were based on attenuated values. The TMDL is based on attenuated load and that was the basis for arriving at the 49.2% calculation that was later verified by SMAST modeling.

However, it's important to understand that each of the subwatersheds of a watershed-embayment system, regardless of being in the same or different towns, have different attenuation factors. The only way to apply the standard percent reduction to a town's unattenuated load is to apply it evenly to each subwatershed because each subwatershed within a Town can have different attenuation factors and as a result generate different outcomes at the sentinel location.

For most towns this means reducing the septic load, as this load in the Popponesset Watershed represents 63 percent of all the loads (Figure 2.6a) and 84 percent of the controllable watershed loads (Figure 2.6c) and is the easiest controllable load to reduce. By reducing this load and to compensate for the loads that cannot be controlled from atmospheric deposition and benthic flux (Figure 2.6a), the load that finally reaches the estuary as an attenuated load is sufficient to comply with the 0.38 mg/L system threshold nitrogen concentration at the sentinel station. The actions a town would propose to meet their target will require further scenario runs because the attenuation factors for each subwatershed are different.

Towns sharing a watershed resource elsewhere are free to decide on another approach for their watershed wide reductions. Deciding where to reduce the unattenuated loads can make a huge difference in terms of effectiveness and cost. Also, the reduction of all existing nonpoint source loads that go beyond septic loads will not be easy, as it includes impacts from fertilizers and stormwater runoff from impervious surfaces. Also important to remember, towns in coastal watersheds that already exceed their nitrogen limit will continue to grow. With this in mind, towns must plan for the future to address the loads that already exceed the carrying capacity of these estuarine ecosystems. They must plan for buildout conditions that zoning allows, accommodating this future growth, while protecting water quality that promotes healthy eelgrass and benthic animal habitat.

Ultimately, the reduction of nitrogen discharged by each town reduces the watershed loads before it has secondary impacts to down-gradient lakes and ponds. It reinforces the message that everyone living in the watershed is responsible for its share of reduction through a MassDEP approved CWMP. Secondly, it was reasoned that it does not require model runs and defines each town's reduction through a simple subtraction. In addition, the equal reduction method establishes the means to calculate an allocation for each town and sub-watershed. The allocated load could be achieved by each town individually or by purchasing reductions if an adjoining town is able to reduce the load more cost effectively.

2.8.5 Calculating the Town Nitrogen Load

It must be understood that the MEP uses the attenuated load to determine the effect of the land based nitrogen load on coastal water quality at the sentinel station. As such, it's the attenuated load from each town and its subwatersheds that is the significant factor. It's important for the reader to understand that the nitrogen reductions required by each town to achieve the threshold concentration must take into account, on a site-specific subwatershed basis, the fact that each sub-watershed's capacity to attenuate a nitrogen plume will vary because the "natural attenuation factors" vary in number but also in magnitude.

As a consequence, calculating a town load reduction must first take into account the site-specific attenuation factors affecting nitrogen denitrification within each subwatershed. This means wastewater management planning to determining what load must be reduced, must begin by back calculating from the attenuated load that affects the sentinel station from each subwatershed. Back calculating requires an understanding where attenuation will or will not take place in each subwatershed. Each time adding the percentage gained based on the number and magnitude of each natural attenuation factor until the sub-watershed's headwaters location has been reached. Technically this is the unattenuated load that must be reduced for that subwatershed of the town. Following similar calculations for other subwatersheds, the town will identify its unattenuated load for reduction. Thus, when planning the 50.8 percent load maximum, town planners will need to take the attenuation factors within each subwatershed into account when they decide where the loads must be reduced and by how much. When decided, it will be the unattenuated load that will be identified for reduction.

MassDEP calculated the attenuated and unattenuated loads for each subwatershed before calculating the attenuated loads for each town. As we know, some subwatersheds will have a greater reduction from natural attenuation because of the number of lakes and ponds the nitrate-contaminated groundwater passes through. Other subwatersheds, without lake and pond attenuation factors will not "see" a nitrogen reduction at all.

2.8.6 Follow-Up

The load targets proposed by the Pilot Team, as a shared responsibility, provide a useful tool for towns to consider. It is, however, only one approach. Towns should discuss and agree if this makes sense to them. Once decided, the Towns may chose to work on this alone or to collaborate for a joint proposal through an inter-municipal agreement that addresses the required watershed wide reductions.

Yet, the town-by-town approach may unnecessarily duplicate planning efforts and may not be the most environmental and cost effective approach for deciding where and how much to sewer within the watershed. It also requires time and money for the model runs to calculate the single town, subwatershed-wide percentage reductions that are needed to meet the targets. It also creates a potential problem of "over-controlling" nitrogen.

As there are many factors at play in decision making for reducing nitrogen loads (type of treatment, where and how much to sewer), with some sub-watershed locations more cost-effective than others, the Team decided this issue is best decided by the leadership of each community. As a first step, at their May 2007 meeting the Team agreed that they had accomplished as much as they could. Their appointment to the team by their communities did not authorize them to do more than to participate and contribute to the dialogue on a shared responsibility to reduce nitrogen loads by promoting inter-municipal watershed-wide, regional planning. Their role was strictly related to wastewater management planning and as such they were not in any position commit their town to do more.

They did not have the authority to act as liaisons to their towns or commit their towns to the Pilot Project Team's findings and recommendations. To complete their charge, the Pilot Team decided it should first focus on a presentation of its findings and recommendations on wastewater management to their town's leadership.

It was agreed that the presentation would discuss the topics.

- The town-by-town nitrogen allocation;
- The equal percent reduction for each town;
- The attenuated nitrogen load affecting the Bay from each town vs. the unattenuated load discharged to the watershed;
- The progress each community has made or is undertaking to reduce nitrogen loads to the watershed;

- The makeup of and tasks for an inter-municipal committee for a Popponesset Bay CWMP – discussing whether the current committee makeup of the Popponesset Bay Project is a useful model, discussing and agreeing on the nitrogen reduction measures and costs that would be pursued to the Popponesset Bay Watershed as a whole

It was the hope that these presentations would lead to inter-municipal dialogue and agreement on a course of action that would lead to a Memorandum of Agreement to address the "fair share" reductions proposed by the Team. Ultimately, to address these matters, an inter-municipal planning committee on such matters may be necessary with membership authorized by their towns for advice on how to proceed; or to take advantage of the CWMP currently in preparation by the Town of Mashpee that addresses the required reductions for the entire Popponesset Bay Watershed.

The first presentation by the Pilot Project was to the Town of Sandwich's recently appointed Water Quality Advisory Committee (WQAC) at its first meeting in November 2007. A presentation was also presented by Mashpee's CWMP consultant engineers, Stearns and Wheler. Topics discussed were the Pilot Project Team's accomplishments; including the MEP methodology, how the MEP data was used to derive the "fair-share" percentage nitrogen reduction, and the proposal for an inter-municipal committee with the authority to represent each town's interest in CWMP planning and implementation. The Pilot Project's findings and recommendations, identified below, resonated favorably with the WQAC.

- An inter-municipal committee representing the views and interests of each town saves money for a CWMP that the town would not have to fund on its own;
- Time is still on their side to partner with the Town of Mashpee for a CWMP that could address Sandwich's needs as well (far better than waiting until the 30-day MEPA comment period when the final CWMP is under review for approval by EOEEA); and
- The ability to perform nitrogen reduction scenario runs as an inter-municipal planning committee for the important CWMP decisions concerning best locations for sewering, treatment and groundwater discharge with the goal of achieving the most cost effective environmental benefit – not to mention the implications related to nitrogen trading among the three towns.

Unfortunately, at the time of this meeting, the Town of Sandwich had not initiated any wastewater related planning to address the TMDLs that had been prepared for Popponesset Bay and the Three Bays watersheds – nor had Sandwich been able to identify available funding to initiate such planning.

During May 2008, the Sandwich Board of Selectmen had authorized the town to hire a consultant to advise the Water Quality Advisory Committee on all maters related to the MEP and the planning that is underway in the Towns of Mashpee and Barnstable. Unfortunately, this authorization must wait until funding becomes available to the Town from the Commonwealth, as the town had budget constraints to sustain existing programmatic needs.

The second presentation before the Mashpee Sewer Commission in December 2007 also resonated favorably. It was clear that the Town of Mashpee is open to developing a cooperative agreement with the Towns of Barnstable and Sandwich that could include the provision for an inter-municipal committee for CWMP implementation, including adaptive management. To further such an endeavor, it was recommended during one of the last meetings of the Pilot Project that the towns of Sandwich and Barnstable should include a provision in their CWMP for collaborative implementation of their CWMPs.

To this end, the video that was completed recently by the Pilot Project will be the vehicle to introduce the Pilot and hopefully enlist interest and participation through a formal working agreement with the Town of Mashpee as it plans to undergo additional scenario runs for deciding the best locations to sewer within the watershed as a whole that also includes locations within Sandwich and Barnstable. It was agreed by all that the opportunity to develop a formal working arrangement that utilizes the CWMP the Town of

Mashpee is preparing is one that should not be missed. The CWMP in preparation by Mashpee should be the vehicle to define the three town's joint needs. It would afford the opportunity to assess how a jointly planned proposal for reduction could achieve the results that affords the possibility for buying nitrogen credits for work that would be more cost and environmental beneficial if the reductions are addressed in the next town.

The process for promoting a formal working relation between the towns, utilizing the CWMP by the Town of Mashpee, has begun. Presentations are planned this September when this report is published and if all goes well the towns will consider the value of a jointly prepared CWMP that addresses their portion of the watershed, including the cost of implementation and the environmental benefits within their town and neighbor's for the watershed and embayment resource they share.

The rest will be up to the towns' leadership. Will they jointly explore and develop joint strategies for nitrogen reduction that coincides with the recommendation of the Pilot or go beyond the calculations of their relative contribution? Time will tell.

2.9 Final Thought

The plan towns prepare, either alone or jointly, for the reductions identified in one or more scenario runs are the best estimate of the required reductions from the watershed. The science behind this project is the best it can be, but there are limits in how these estimates can be used, as no model is fail safe. Secondly, the parcel data that is collected to define current watershed loads of nitrogen from nonpoint sources of pollution will soon become outdated. For this reason, plans may need to assess whether the buildout projections should be further refined to address future load estimates. What is also important to understand, growth will always be a factor in this equation but this equation will always have a limit that should not be exceeded for each embayment system. The fact that these loads have been from nonpoint sources will not make the resolution of this problem easy. It is important to understand that most embayments systems can achieve their thresholds without 100 percent sewering. The correct mix of treatment options and locations for sewering should be determined through additional scenario runs, hopefully through the involvement of the towns sharing the resource area with its high dependence on on-site septic systems, estimated at over 83 percent of the controllable load. The load limit that the estuary should "see" from the watershed is one that town planners sharing this resource will need to evaluate as an ongoing, shared responsibility; making sure treatment capacity within the watershed is adequate and treatment capability for keeping loads at levels that are protective of a restored habit or through restoration through adaptive management, until those conditions have been restored and maintained.

Chapter 3: Three Bays Pilot Project

Figure 3.1 Aerial photo of the Three Bays Embayment System showing the two outlets that impede tidal exchange with Nantucket Sound
Photo courtesy of Three Bays Preservation, Inc.

Figure 3.2 Floating Algal Mats at Warren's Cove
Photos courtesy of Three Bays Preservation, Inc.

3.1 Three Bays Watershed Facts

Key Feature	TMDL implementation in a tidal estuary
Project Name	Three Bays Watershed and Embayment System Inter-municipal Watershed TMDL Implementation
Scope/Size:	Watershed area: 20.5 square miles (ca. 12,942 acres); approximately 9 miles north to south and just over 3 miles east to west.
Land Type	17% rural undeveloped, urbanizing with 32% residential, 2% limited agriculture
Pollutant	Nitrogen
Wastewater Infrastructure	Watershed is without municipal sewer; is dependent on residential on-site septic systems with the exception of two wastewater treatment facilities, the Horace Mann Charter School and the Cotuit Landing Shopping Plaza.
Hydrology	The Three Bays system consists of five embayments (Cotuit Bay, West Bay/Eel River, North Bay, Prince Cove and Warren's Cove). This embayment system exchanges tidal water with Nantucket Sound through two maintained inlets at both the east and west end of Sampson Island. *
TMDL Development	Nonpoint source nitrogen discharges primarily from residential on-site septic systems and secondarily from fertilizers use associated with cranberry bogs and golf course turf management.
Data Sources	Towns of Barnstable, Mashpee, and Sandwich; Cape Cod Commission; Massachusetts Department of Environmental Protection; University of Massachusetts at Dartmouth - School of Marine Science Technology (SMAST)
Data Mechanisms	Water quality monitoring results, watershed/parcel specific defined estimates of nitrogen loading based on drinking water use records, USGS delineation of groundwatersheds, and MEP Linked Watershed-Estuary Nitrogen Management Model (Linked Model) for calculating load thresholds.
Monitoring Plan	A continuing "funded" commitment at least to 2010 at this time.
Control Measures	Board of Health regulations, two-acre zoning, and stormwater runoff restrictions.

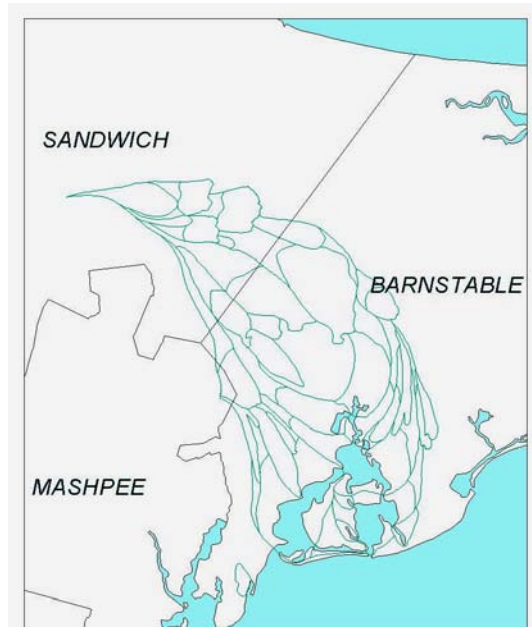
* A complete description of all 5 embayments is presented in Chapters I and IV of the MEP Technical Report (Howes, B. et al., 2006)

3.2 The Three Bays Watershed

3.2.1 General Description

The Three Bays Watershed consists of five main subembayments: Cotuit Bay, West Bay/Eel River, North Bay, Prince Cove and Warren's Cover. The estuarine reach of the Marstons Mills River is considered part of the Prince Cove/Warren's Cove subembayment system flowing into the head of North Bay in the modeling and thresholds analysis (Figures 3.3-3.5).

The Three Bays embayment system exchanges tidal water with Nantucket Sound through two inlets at the east and west ends of a barrier beach, referred to as Dead Neck/Sampson Island (Figure 3.1). The eastern most inlet connecting Nantucket Sound to West Bay was opened by dredging in 1900 and is armored on both the Oyster Harbors Beach/Dead Neck side as well as the Wianno Beach side.



The Three Towns of the Three Bays Watershed

These sub-embayments constitute important components of each Town's natural and cultural resources. However, the nature of these enclosed sub-embayments in close proximity to populous regions of the watershed brings two opposing elements to bear: 1) as a protected marine shoreline they are popular for boating, recreation, and land development and 2) as enclosed bodies of water, the pollutants they receive may not be readily flushed due to the proximity and density of development along their shores.

The watershed drainage area consists of 13,717 acres and 21 sq miles and ~ 6.9 miles north and south and ~ 3.6 miles east and west (Table 3.1, Figure 3.3). The major bay, consisting of Cotuit, West and North Bay is roughly 2 miles long and a slightly over two miles wide - shore-to-shore (Figure 3.4).

Table 3.1 Three Bays Watershed Land Area by Town

TOWN	Town Area within Three Bays Watershed *		
	Acres	**Square Miles**	**Percent**
Barnstable	10,944.30	17.10	79.78%
Mashpee	84.94	0.13	0.62%
Sandwich	2,688.04	4.20	19.60%
Total	13,717.28	21.43	100.00%

* Area includes all water, including estuarine

The entire Three Bays system has a surface coverage of 13,717 acres, including several small subembayments attached to the system's main sub-embayments (Figures 3.3 – 3.5). Cotuit Bay is the largest sub-embayment of the Three Bays system, covering 469 acres and an average depth of 6.2 ft. West Bay has area coverage of 343 acres and an average depth of 5.3 ft. North Bay has area coverage of 309 acres, and an average depth of 5.3 ft. Prince Cove together with Warren's Cove and the Marstons

Mills River are the northernmost reaches of the Three Bays system, with 93-acre coverage. The Marstons Mills River is the largest surface source of fresh water into the estuary.

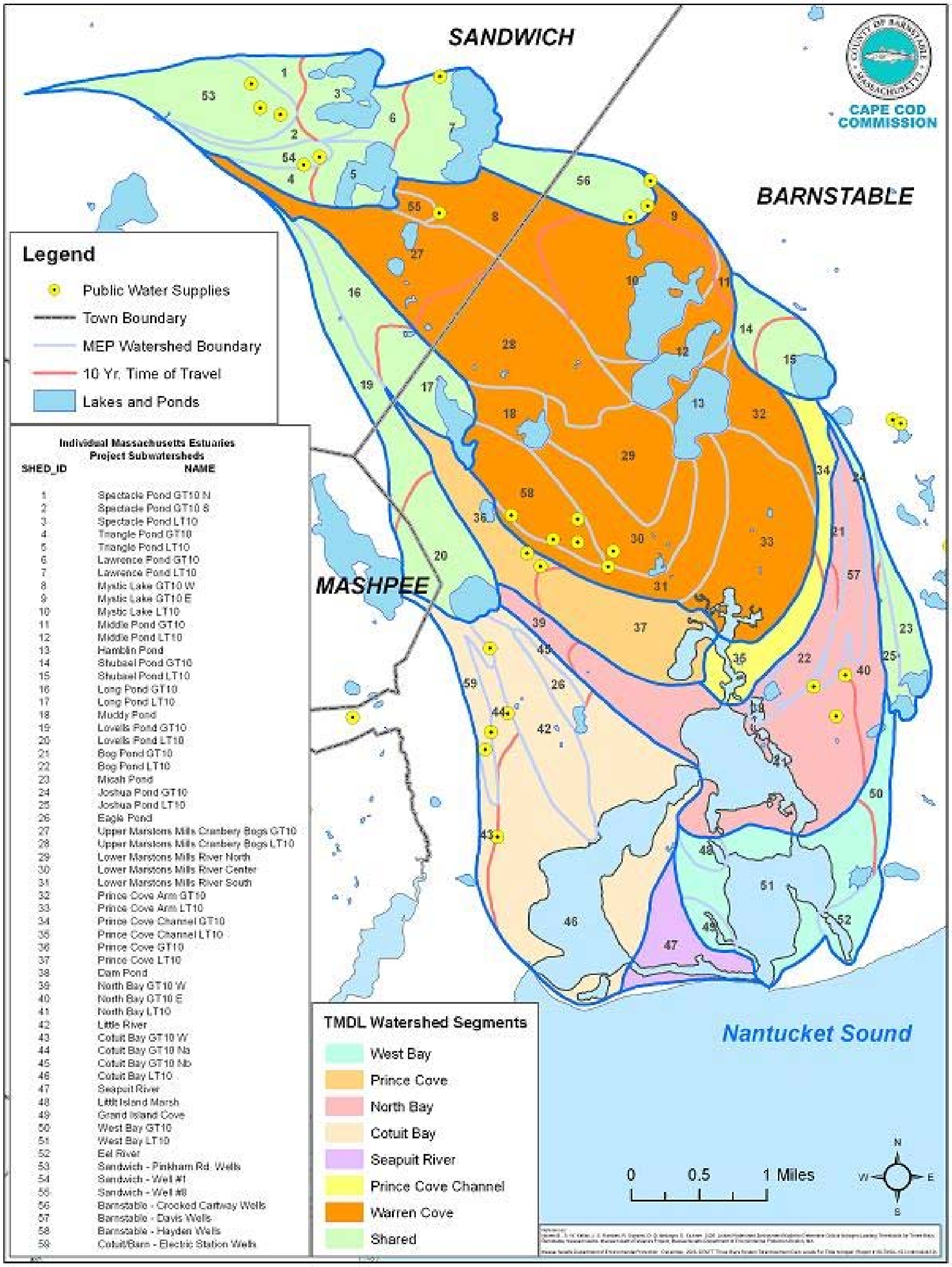


Figure 3.3 Three Bays Sub-embayments: Cotuit Bay, West Bay, North Bay, Prince's Cove, Warren's Cove and Little River, Marstons Mills River and Seapuit River

Figure 3.4 Three Bays Embayment System: Tidal waters enter the Bay through two inlets from Nantucket Sound. Freshwaters enter from the watershed primarily through 2 surface water discharges (Marstons Mills River and Little River) and direct groundwater discharge.

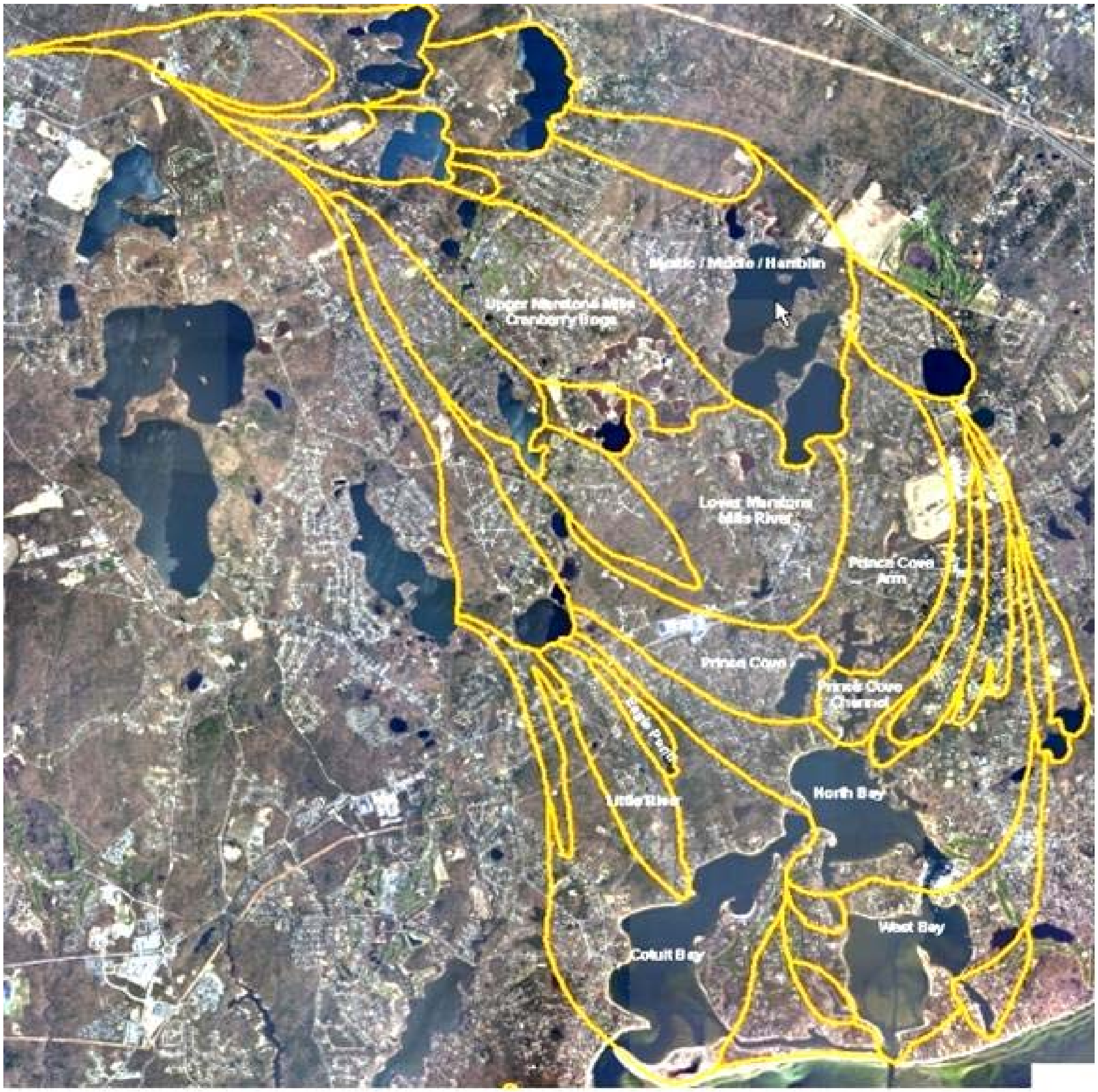


Figure 3.5 Three Bays Sub-watersheds: Cotuit Bay, West Bay, North Bay, Prince/Warren's Cove, Little River, and Marstons Mils River

Eighty percent of the 21.43 square mile watershed area is within Barnstable (Villages of Cotuit, Osterville, Marstons Mills), followed by the town of Sandwich at almost 20 percent, with the Town of Mashpee with less than 1 percent (Table 3.1).

The tidal portion of the Prince Cove and Warren's Cove sub-embayments (Marstons Mills River), including the upper portion of North Bay display large salinity fluctuations and contain the greatest diversity of estuarine habitats and most of the Three Bay's salt marsh area and shallow tidal flats (Figure 3.4). In contrast, Cotuit Bay and West Bay show more typical embayment characteristics dominated by open water areas, small fringing salt marshes, relatively stable salinity gradients and relatively large basin volumes relative to tidal prism. Although the upper two sub-embayment systems up-gradient of North Bay and the open water portions of Cotuit Bay and West Bay exhibit different hydrologic characteristics (river dominated versus tidally dominated), the tidal forcing for these systems is generated from Nantucket Sound. Nantucket Sound, adjacent Dead Neck (Oyster Harbors Beach), exhibits a moderate to low tide range, with a mean range of about 2.5 ft. Since the water elevation difference between Nantucket Sound and the Three Bays system is the primary driving force for tidal exchange, the local tide range naturally limits the volume of water flushed during a tidal cycle (by comparison, note the tide range off Stage Harbor Chatham is ~4.5 ft and Wellfleet Harbor is ~10 ft).

This southern coastal region of Cape Cod between the Cotuit Bay and West Bay entrances can be considered a moderately dynamic region, where natural wave and tidal forces continue to reshape the shoreline. Due to the protection afforded by the islands of Martha's Vineyard and Nantucket, the south shore of Cape Cod is protected from the influence of long period open ocean wave conditions. Similar to many portions of the Massachusetts coast, the available sediment supply influences the migration and/or stability of tidal inlets. Tidal inlets can become overwhelmed by the gradual wave-driven migration of a barrier beach separating the estuaries from the ocean. In addition to these natural coastal processes, man-made structures often can influence the stability of a shoreline/tidal inlet system.

3.2.2 Geology and Hydrogeology

The Three Bays sub-embayments are of varying size and hydraulic complexity; each defined by their rates of flushing, salinity, and shallow depths and their proximity to a heavily developed and populated sub-watershed.

The hydrogeology of this watershed, like most of Cape Cod, consists predominantly of glacial deposits of sand and gravel (see: http://www.capecodgroundwater.org/groundwateredpage/groundwater.pdf). These highly-permeable soils are a major pathway for nutrient transfers from sub-watersheds to the adjacent coastal waters in this region. The presence of both groundwater and surface water pathways for input of nutrients into this and other Cape Cod estuarine systems has a significant impact on its response to changing nutrient loadings from changing land-uses with the surrounding watershed. Overall, this coastal watershed area consists of several small and large glacial kettle-hole ponds with the Marstons Mills River as the major contributor of freshwater to the system.

Unlike off Cape locations where surface topographic features characterize a watershed's boundary and drainage pattern, Cape Cod's groundwatersheds are defined by the elevation and direction of flow of its water table (Cambareri and Eichner 1998, Millham and Howes 1994 a, b). The Sagamore Lens is the contributing source of the Three Bays groundwater. This aquifer's convex shape causes it to resemble a lens and it is often referred to as the freshwater lens. The separation of this freshwater lens and the salt groundwater beneath causes the characteristic lens curvature - resulting from its buoyancy and the greater density of the underlying saltwater (see: http://simlab.uri.edu/cara/geology_groundwater.htm). This groundwater system is also the recipient of the nitrogen loads from land use (wastewater discharges, stormwater runoff, and fertilizers) and atmospheric deposition on the watershed.

3.2.3 Water Quality

Habitat and water quality assessments were conducted throughout the Three Bays system utilizing available water quality monitoring data, recorded historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure. At present, the Three Bays embayment system is showing significant impairment to severely degraded habitat quality in the Prince Cove and Warrens Cove sub-embayments as well as the upper portion of North Bay. The lower portion of North Bay as well as the Eel River are showing indications of moderate impairment, bordering on significant impairment, while Cotuit Bay and West Bay are both showing signs of moderate impairment (Table 3.2).

The impairment of water quality from nitrogen enrichment is frequently manifested from oxygen depletion during the evening hours when all biological systems within the embayment utilize the dissolved oxygen for their oxidative metabolic processes; however, during the day the oxygen levels rise

Table 3.2 Embayment Waters within the Three Bays System on the 2006 Integrated List

Waterbody Name	Waterbody Segment	Description	Size	Pollutant Listed
Cotuit Bay	MA96-63_2004	From North Bay at Point Isabella oceanward to a line extended along Oyster Harbors Beach, Barnstable.	0.85 sq mi	-Nutrients -Pathogens[1]
North Bay	MA96-66_2004	From Fox Island to just south of Bridge Street and separated from Cotuit Bay at a line from Point Isabella southward to the opposite shore (including Dam Pond), Barnstable.	0.47 sq mi	-Nutrients -Pathogens[1]
Prince Cove	MA96-07_2004	Includes adjacent unnamed cove east of Prince Cove to North Bay at Fox Island, Barnstable.	0.14 sq mi	-Nutrients -Pathogens[1]
Seapuit River	MA96-64_2004	South of Osterville Grand Island to Cotuit Bay and West Bay, Barnstable.	0.06 sq mi	-Pathogens[1]
West Bay	MA96-65_2004	South of the Bridge Street bridge to Nantucket Sound including Eel River, Barnstable	0.52 sq m	-Nutrients

significantly above atmospheric equilibration levels because these systems are dominated by phytoplankton (or epiphytic algae) which release oxygen as a byproduct when they undergo photosynthesis. The level of oxygen depletion, the magnitude of daily oxygen excursion and the elevated chlorophyll a levels indicate a highly enriched estuary with an impaired habitat quality. As shown in Table 3.3, Cotuit Bay, West Bay, North Bay and Prince Cove undergo seasonal oxygen stress with oxygen levels less than 6 mg/L, consistent with nitrogen enrichment and elevated levels of chlorophyll a from the phytoplankton algal blooms throughout the embayment's water column. As a result of these turbid water (high chlorophyll a) conditions, the eelgrass beds that were once supported within this system (Figure 3.7), restricted to the shallows of North and Cotuit Bays or to Prince Cove and West Bay, are no longer present.

In view of these and past and recent water quality studies that confirmed water quality degradation, the Cotuit Bay, North Bay, Prince Cover, Seapuit River, and West Bay sub-embayments have been listed as waters requiring TMDLs (Category 5) in the MA 2006 Integrated List of Waters. This report can be found at http://www.mass.gov/dep/water/resources/2006cmt2.pdf (Table 3.2). The environmental damage affecting these embayments includes pollutant loadings from nutrients and pathogens, periodic decreases of dissolved oxygen, decreased diversity of benthic animals, and algal blooms.

The major indicators of habitat impairment, resulting from excess nutrient loadings, is fully detailed in Chapter VII, Three Bays MEP Technical Report "Assessment of Embayment Nutrient Related Ecological Health" (http://www.oceanscience.net/estuaries/report/3Bays/Chapter7_3Bays_MEP.pdf).

Table 3.3 Major water quality indicators of habitat impairment observed in the Three Bays System

Waterbody Name	Eelgrass Loss[1]	Dissolved Oxygen Depletion	Chlorophyll *a*[2]	Macro-algae	Benthic Fauna[3]
Prince Cove	100%	< 6 mg/L up to 60% of time < 4 mg/L up to 27% of time SI/SD	>10ug/L up to 93% of time >20 ug/L up to 63% of time SI	MI	SD
Upper North Bay	100%	< 6 mg/L up to 66% of time < 4 mg/L up to 24% of time SI/SD	>10ug/L up to 68% of time >20 ug/L up to 10% of time MI/SI	No data	SD
Lower North Bay	100%	< 6 mg/L up to 46% of time < 4 mg/L up to 1% of time MI/SI	>10ug/L up to 24% of time >20 ug/L 0% of time MI/SI	No data	MI/SI
Cotuit Bay	100%	< 6 mg/L up to 73% of time < 4 mg/L up to 1% of time MI/SI	>10ug/L up to 32% of time >20 ug/L up to 2% of time MI	MI	GF/MI
West Bay	100%	< 6 mg/L up to 49% of time < 4 mg/L up to 19% of time SI	>10ug/L up to 14% of time >20 ug/L 0% of time GF/MI	MI	GF/MI
Warrens Cove	100%	SI/SD	SI	SD	SD

[1] Based on comparison of present conditions to 1951 Survey data.
[2] Algal blooms are consistent with chlorophyll *a* levels above 20ug/L
[3] Based on observations of the types of species, number of species, and number of individuals

GF – Good to Fair – little or no change from normal conditions*
MI – Moderately Impaired – slight to reasonable change from normal conditions*
SI – Significantly Impaired- considerably and appreciably changed from normal conditions*
SD – Severely Degraded – critically or harshly changed from normal conditions*

- These terms are more fully described in the 2003 MEP report "Site-Specific Nitrogen Thresholds for Southeastern Massachusetts Embayments: Critical Indicators", (http://www.mass.gov/dep/water/resources/nitroest.pdf).

3.2.4 Eelgrass Habitat

The first field surveys of the Three Bays in 1951 documented eel grass beds with significant coverage throughout the shoreline of the Three Bays (Table 3.4, Figure 3.7 (Charles Costello, MassDEP Eelgrass Mapping Program communication) suggesting these waters were of high quality without the impacts associated with nitrogen loading. However, follow-up MassDEP field surveys in 1995 and in 2001 identified an embayment system with a significant decline in eelgrass coverage, from a coverage of 151 acres in 1951 to 11.5 acres in 1995. Unfortunately, the nitrogen loads affecting this embayment system have been sufficient to stimulate the growth of microalgal blooms during the warm summer months at sufficient densities (high chlorophyll a levels exceeding 20 μ/L)) (Table 3.3, Figure 3.6)) in the water column that prevents the seabed from receiving adequate sunlight exposure to sustain the eelgrass beds. As a result, the eelgrass beds that were first identified in 1951 have since been replaced by macroalgae, which are undesirable because they do not provide the high habitat quality for fish and invertebrates. Until the water column nitrogen levels are reduced and under control from their contributing sources, it is unlikely these eelgrass ecosystems will be reestablished as habitat and spawning ground, nursery, and protective cover for commercially important finfish, and shellfish.

Figure 3.6 Floating Algal Mat and Phytoplankton Bloom at South Prince Cove displaying limited light transparency
Photo courtesy of Three Bays Preservation, Inc

Table 3.4 Three Bays Eel Grass Acreage (Past and Present)

Embayment	1951 (Acres)	1995 (Acres)	2006 Acres)	Percent Loss
Three Bays	125	11.2	0	100

3.2.5 Sentinel Station

The upper region of the Narrows between North Bay and Cotuit Bay (at the entrance to the Narrows) was selected as the best location for the sentinel station for the Three Bays embayment system. This location was selected because: (1) it is relatively deep (reflecting the larger Three Bays basins) and it supported a major eelgrass bed in the 1951 survey; (2) achieving the threshold nitrogen level at this location will result in high quality habitat conditions throughout Cotuit and West Bays; (3) restoration of nitrogen concentrations at this location should result in conditions similar to 1951 within Prince and Warren's Coves and North Bay; (4) nitrogen levels restorative of eelgrass beds at the sentinel location should provide for marginal beds in the shallows of Prince Cove and North Bay and (5) achieving the threshold nitrogen level at the sentinel location will require removal of sufficient nitrogen related stress as to restore infaunal animal habitat in the adjacent deeper waters of Prince Cove and North Bay.

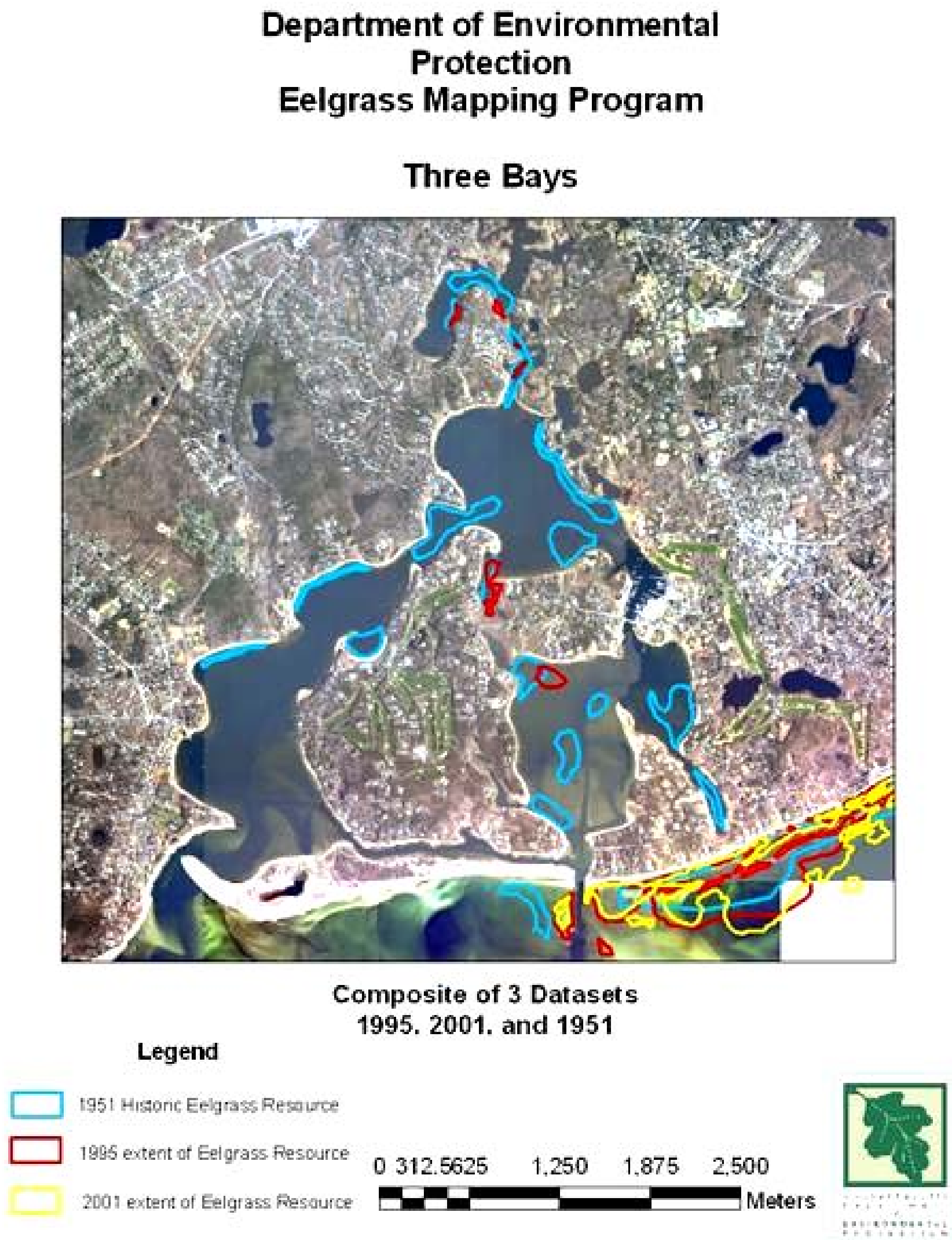


Figure 3.7 Eelgrass Beds past and present distribution in the Three Bays embayment system

Based on current conditions, the infaunal analysis (Chapter VII, MEP Technical Report (Howes et. al., 2006) coupled with the nitrogen data (measured and modeled), indicated that the target nitrogen concentration of 0.38 mg/L at the sentinel location and 0.40 mg/L TN L-1 within the marginal regions (shallows) of North Bay was set for the restoration of eelgrass in this system of high quality infauna habitat within the Three Bay System.

This secondary level to check restoration of marginal beds in North Bay (0.40 mg TN L-1) is consistent with the analysis of the restoration of eelgrass beds at a reference site in nearby Great Pond in Falmouth, where eelgrass beds in deep water could not be supported at a tidally averaged TN of 0.412 mg TN L-1 at depths of 2 meters. Currently, as reported in the Three Bays SMAST Technical Report, the existing nitrogen level at the sentinel location at mid-ebb tide is 0.581 mg/L TN L-1.

3.2.6 Watershed Land use

Land use in the watershed, as identified in the Three Bays Technical Report, is predominantly residential and public municipal and public/private open space, with nearly half of the lots with single-family homes (Figure 3.8). Residential land use represents slightly less than half (46%) of the watershed area. Public service (government owned lands including open space, roads, and rights-of-way) is the second highest percentage of the watershed (28%). In addition, 76% of the parcels in the system watershed are zoned as single family residences (MADOR land use code 101) with single family residences accounting for 88% of the residential land area. In addition, residential land uses are the predominant land use in all the major Three Bays subwatersheds with a range of 39% to 63% of the subwatershed areas. Public service land uses are the second highest percentage in all of the major subwatersheds except for the Seapuit River subwatershed where undeveloped land uses are the second highest. Overall, undeveloped land uses account for 11% of the Three Bays watershed (Figure 3.8). It's important to understand how this landuse category is defined, since the classification of undeveloped land use as presented later on this report (section 3.4.1) also includes lands held for conservation/open space purposes such as parks, golf courses, and agriculture. Commercial properties account for 2% of the Three Bays watershed area.

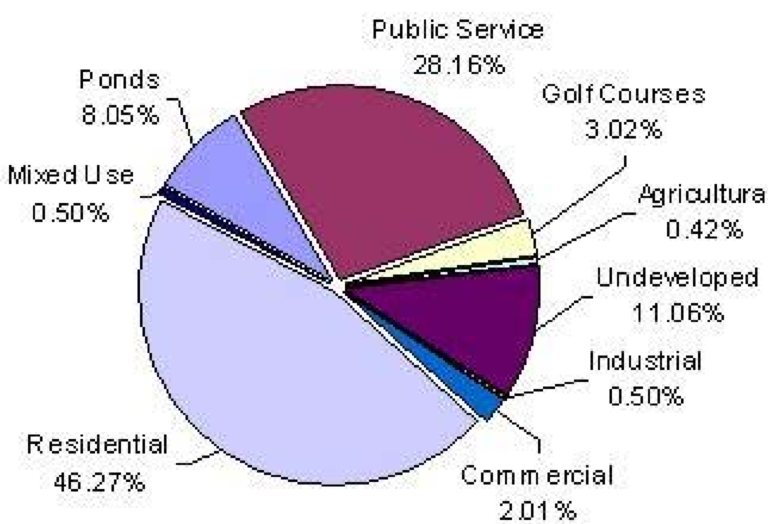


Figure 3.8 Three Bays Watershed Land Uses
Source: MEP Technical Report, Chapter 4, p.30, Figure IV-2

Vegetative cover consists primarily of a mixture pine, locust, and oak with limited agricultural production, confined to cranberry production.

3.3 Sources of Nitrogen

The nitrogen sources affecting estuarine water quality are many and collectively have an impact. Table 3.5 and Figure 3.9a-c identify the three major sources: atmospheric loads (atmospheric deposition), sediment regeneration (benthic flux) and those contributed from the watershed from both natural and anthropogenic sources. Figure 3.9a-c are presented to define a better understanding of the loads affecting water quality from estuarine and watershed sources and the percentage of those watershed sources that can be controlled by wastewater management practices. As presented in Figure 3.9a, it is clear that the loads contributed to the Three Bays estuary are not always from the watershed. Clearly, on-site septic system loads represent 67 percent of the overall combined overall load (watershed and atmospheric deposition to the estuary) and 83 percent of the watershed's controllable load (Figure 3.9c).

Because the contributions from atmospheric deposition and those recycled from the sediment are not loads that can be controlled by any watershed-based management strategy we are left with the overall watershed loads (Figure 3.9b) and those that can be controlled (Figure 3.9c).

Table 3.5 Sources of Nitrogen Loads to the Three Bays Embayment and Watershed System

Source	Kg N/Year
Title 5 Wastewater	53584
Stormwater Runoff	2828
Lawn Fertilizers	7920
Water Body Surface	8555
"Natural" Sources	1641
Package Treatment Plants	39
Estuarine Atmospheric Deposition	5712.25
Unattenuated Load	80279.25

Clearly, the reduction of the septic load, representing 83 percent of the controllable (stormwater, fertilizers, package treatment plants) watershed load is the source that must be controlled and also the subject of this and other management plans. The use of the MEP Linked Model for use in defining scenarios for the reduction of nitrogen takes into account the contributions from atmospheric and benthic flux, as it simulates the outcome of any plan for a septic load reduction to address the threshold concentration that must be achieved at the sentinel location in the bay.

3.3.1 Wastewater Treatment Plants and Onsite Systems

The Three Bays watershed is dependent on on-site septic systems with the exception of two package wastewater treatment facilities. These include the Horace Mann Charter School (3907 gpd average daily flow) and the Cotuit Landing shopping plaza (5206 gpd average daily flow) that currently contributes less than 1% (0.06 %) of the total yearly controllable load to Three Bay (Figure 3.9c). The unused capacity of the two treatment plants provides an opportunity to accommodate some capacity, following future wastewater management planning, and to utilize their design flow and denitrifying capability to evaluate the potential of upgrading and extending their use to adjoining neighborhoods with Title 5 septic systems. However, the unused capacity of these package treatment plants is insufficient to provide the capacity needed to reduce the required loads within the watershed for TMDL purposes.

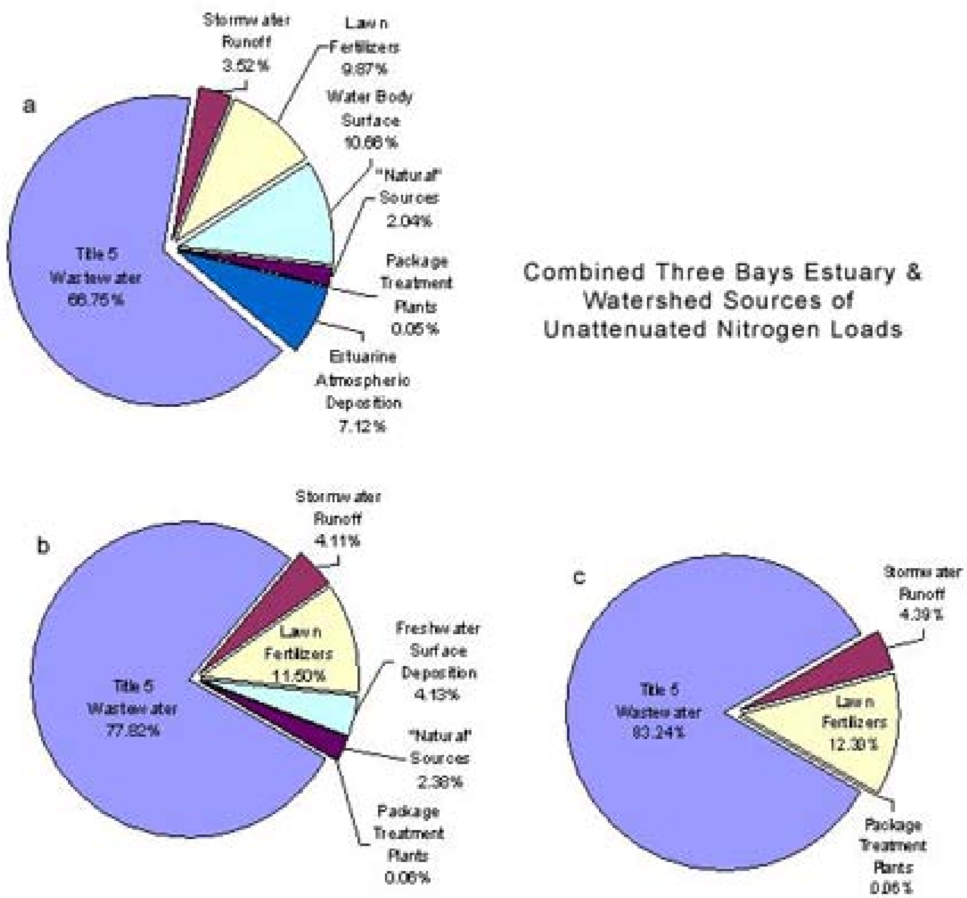


Figure 3.9 a-c Combined Three Bays Estuary and Watershed Sources of (a) Unattenuated Nitrogen Loads (top), (b) Watershed Sources of Unattenuated Loads (bottom Left) and (c) Percentage of the Combined Watershed Loads that are Controllable (stormwater, fertilizers (agriculture, lawns/turf), treatment plants) (bottom right). Source: SMAST Three Bays Technical Report (Howes, B. et. al. 2004), Chapter 4, Table IV-4.

Through the CWMP process, the Town of Barnstable's Comprehensive Wastewater Facilities Plan has been underway for more than a decade; receiving MEPA approval in October 2007 for an increase in its treatment capacity from 2.1 MGL to 4.2 MGD with recharge of treated effluent at the Hyannis Water Pollution Control Facility (WPCF). Construction is underway on the increased capacity of the Hyannis WPCF, with the expected completion in winter of 2009. There were issues of concern about the capacity of the treatment disposal beds to accommodate future flows (above 4.2 MGD). Following years of study for an alternative site for discharge, the decision was made to install piping for the additional flows to an offsite location to a town-owned location near the Community College.

In view of the nitrogen load reductions identified for the Three Bays in the recently released MEP Technical Report (Howes et. al, 2006) and the EPA approved TMDL, the Town of Barnstable is re-evaluating its facilities plan to address the significant nitrogen reductions required from the Three Bays and other embayment systems within the town for which TMDLs have been issued. Since the 1997 MEPA approval had not addressed the significant reduction in nitrogen loads that are needed to restore water quality to these embayments, including Three Bays, town officials are considering use of the increased treatment capacity of the Hyannis facility to accommodate the sewering the town's coastal embayments with nitrogen TMDLs, including the Three Bays. During the filing of this report, the preliminary design layout of the expanded sewer main and pump station locations was under evaluation by the town's consultant to address the nitrogen and bacteria TMDLs that were issued by MassDEP for the watersheds to the impacted southshore embayment systems, including the Three Bays watershed to maximize cost savings and use of existing mains, and pump stations. The issue of water balance still remains; whether the treated wastewater at the Hyannis facility must be returned for disposal at its watershed of origin.

3.3.2 Treatment Plant Discharge Locations

High growth rate MEP communities, similar to Barnstable, face limitations in the siting of wastewater treatment discharges when the only lands available for discharge are within Zones of Contribution (Zone IIs) to public supply wells and coastal watersheds to nitrogen-sensitive estuaries. While the Groundwater Regulations (310 CMR 5.00; http://www.mass.gov/dep/service/regulations/314cmr05.pdf) provide adequate public health protection safeguards for the siting of state permitted wastewater treatment plants within Zone IIs, towns are also exploring increasingly creative options for wastewater disposal in coastal watersheds to nitrogen-sensitive embayments. The Town of Barnstable is currently considering the possibility of utilizing its wastewater treatment facility within the village of Hyannis, as this treatment plant recently completed a significant upgrade in its capacity to treat wastewater. However, the Town is also examining the use of existing town owned properties within the Three Bays watershed and existing, privately permitted small-scale treatment plants to assure that the water withdrawn from public supply wells and discharged as wastewater remains within the watershed of origin.

3.3.3 Stormwater

Sources of water quality impairment also exist from stormwater runoff from impervious surfaces (buildings, parking lots, driveways, and roads). These represent 3.6% of the overall load affecting the watershed and embayment (Figure 3.9a), 4.4% of watershed-wide controllable load and slightly more in sub-watersheds with a greater percentage of developed land (Table 3.5, Figures, 3.9c; and Figure IV-4 of MEP Technical Report (Howes, B. et al., 2006)). Overall, stormwater runoff represents 3.5 percent of the nitrogen load affecting the embayment/watershed system as a whole (Figure 3.9a). Stormwater runoff and fertilizer management are closely related because lawn fertilizer use frequently washes off lawns during rainfall events and becomes part of the runoff load.

The EPA NPDES Phase II stormwater-permitting program that regulates stormwater discharges requires the Town of Barnstable to have a general permit that commits the Town to carry out a variety of Best Management Practices (BMPs). Through Barnstable's zoning requirements (Site Plan Review ordinance, Article IX §240-103 and site development standards (amended 11-15-2001 by Order No. 2002-029; explored further in Chapter 5.2.2)) developers must use best management practices to eliminate the potential of off-site discharges of stormwater.

The Town of Barnstable also has a funded Coastal Mitigation Program which corrects untreated discharges from entering coastal embayments from any Town roadway or property (boat ramps, ways-to-water, etc.). In FY 2008/2009 there were four on going projects under this program in the Three Bays Area.

MassDEP's Stormwater Policies and Guidance (http://www.mass.gov/dep/water/laws/policies.htm#storm) should be consulted for recommended BMPs to control stormwater impacts on surface waters. SMAST has also identified the following BMPs that warrant further investigation for nitrogen removal:

- Vegetated swales
- Retention ponds
- Constructed wetlands
- Sand/organic filters
- Infiltration basins/trenches.

3.3.4 Fertilizer Use

Fertilizer use is the third largest contributor of nitrogen to the Three Bays embayment/watershed system, followed by septic wastewater and freshwater surface waters (Table 3.5, Figure 3.9a). As a controllable watershed load, fertilizer use is the second largest source of nitrogen loading - primarily for residential lawns and golf course greens. Fertilizers accounted for 9.87 percent of the overall Three Bays watershed nitrogen load (Figure 3.9a) and 12.3 percent of the controllable watershed nitrogen load (Figure 3.9c).

Considering that four golf courses (Wiano Golf Club, Oyster Harbors Club, Ridge Club, and Holly Ridge) and the residential lawns that represent 3 and 46 percent respectively of the watershed area (Figure 3.8), with both contributing nitrogen loads from annual fertilizer applications to turf and lawns (12 percent of the controllable load (Figure 3.9c)), it is clear these embayment loads can be controlled with proper use management. The Popponesset Pilot had determined that golf courses contributed 24% of the unattenuated fertilizer load, equal to 2.4% of the total unattenuated controllable load. Also worth considering, nitrogen leaching from fertilizer applications on golf courses can be a larger share of the load in the sub-watersheds when they are located in close proximity to the bay where natural attenuation may not reduce those loads prior to entering the coastal embayment.

3.4 Demographics

3.4.1 Land Use Change

During the past 48 years, land use development pressures within the Three Bays Watershed have been dramatic with a substantial loss of undeveloped land from 88% in 1951 to 47% in 1999 (Table 3.6 and Figures 3.10-3.11). Coincident with this change was a substantial increase in the number of year round single-family homes and the conversion of seasonal to year-round residences. These changes also coincide in nearly a 50 percent loss of undeveloped forest land for suburban use.

Table 3.6 Developed and Undeveloped Land (1951, 1971, 1985, 1999) in the Three Bays Watershed (Source: MassDEP GIS)

YEAR	Developed Acreage	Undeveloped Acreage	Total Acreage *	Percent Developed +	Percent Undeveloped +	TOTAL_PCT
1951	1370	10178	11548	12%	88%	100%
1971	2304	9243	11547	20%	80%	100%
1985	4157	7389	11546	36%	64%	100%
1999	6107	5439	11546	53%	47%	100%

* Exclusive of acreage from lakes and ponds
+ Refer to Figure 3.11 for landuse codes for these two categories of land use.

As one would expect, land development dominated by residential use in an unsewered watershed is expected to result in a diminishment of waters quality to impacted inland and coastal waters from the subsurface discharge of wastewater effluent from residential wastewater disposal systems. These discharges, including those resulting from lawn fertilizer use and stormwater runoff, enter the groundwater system and eventually flow down-gradient to the receiving surface waters of the estuary. The watershed nitrogen load received by the estuary will vary from one sub-watershed to another; in each case dependent on the number wetland systems (lakes, ponds, and marshes) that intercept and denitrify this wastewater plume prior to its discharge to the estuary. In the sandy soils of Cape Cod, these groundwater flows at an average rate of one foot per day.

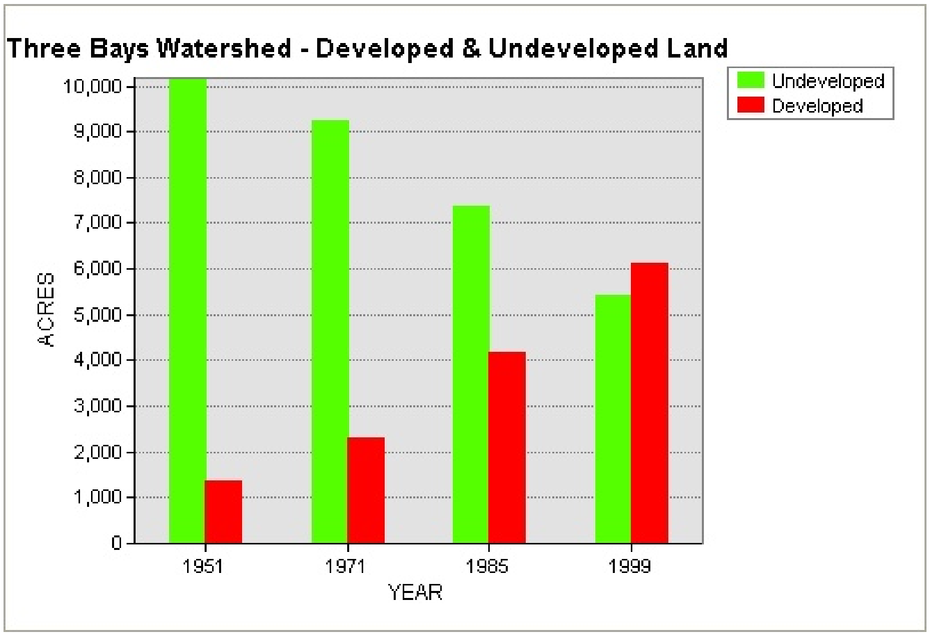


Figure 3.10 Graph showing land use change (1951, 1971, 1985, 1999) in the Three Bays Watershed represented as developed and undeveloped (Source: MassDEP GIS)

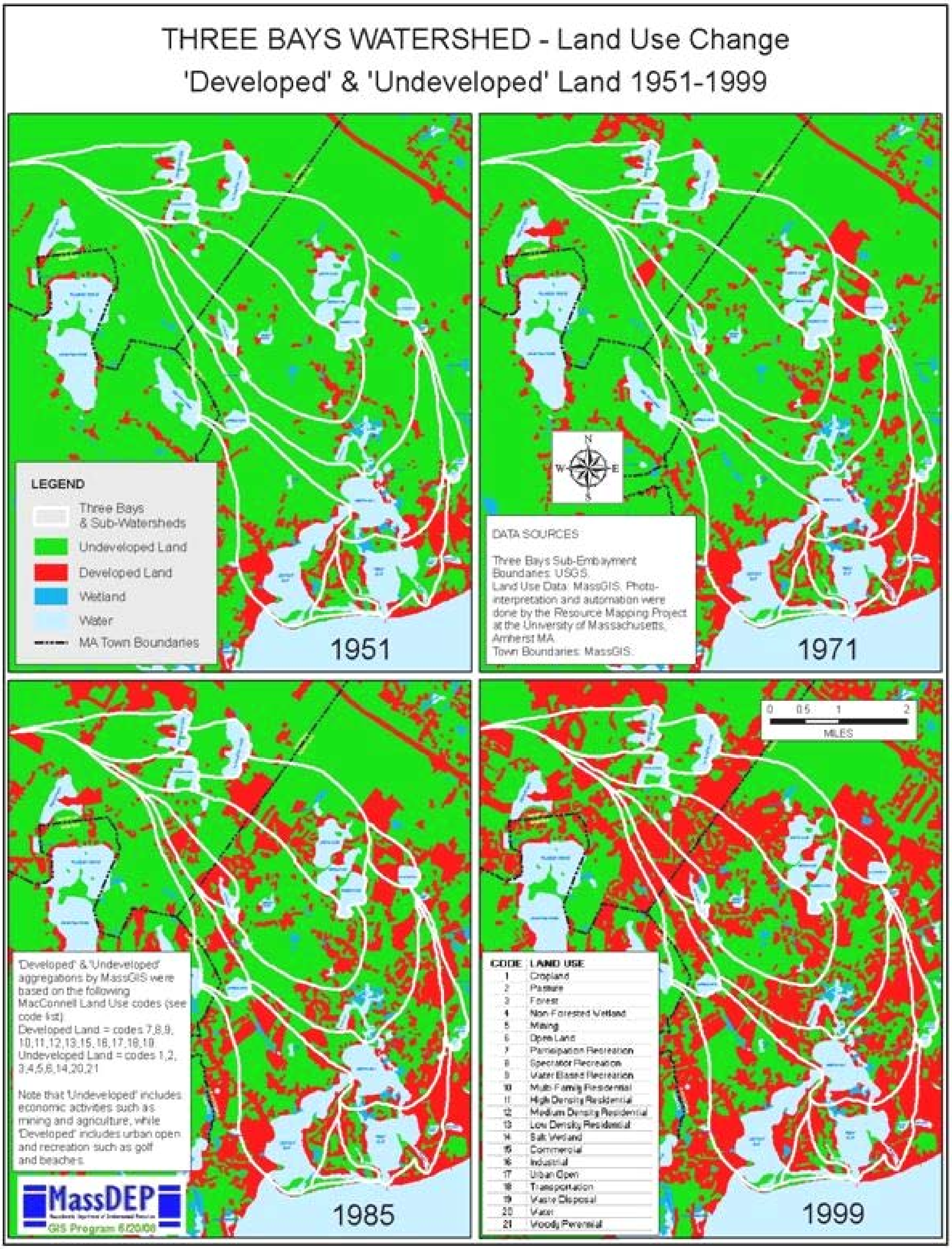


Figure 3.11 Maps showing land use change (1951, 1971, 1985, and 1999) in the Three Bays Watershed represented as developed and undeveloped (MassDEP GIS)

3.4.2 Population Growth

US Census data indicates a population growth and a corresponding decline in open space in the Three Bays watershed shared by the three towns since the 1950s (Table 3.7; Figures 3.12-3.13) with the Town of Mashpee taking the lead in population growth for all time intervals (1950 to 2000; 1990 to 2000; and 2000 to 2006). The highest rate of growth occurred from 1950 to 2000 with a 2856 percent increase, followed by Sandwich at 737 percent and Barnstable at 356 percent. While these rates reflect town wide patterns, they also reflect increases in residential development and wastewater discharges within the watershed from on-site water septic systems.

Dramatic declines in water quality and the quality of the estuarine habitats throughout Cape Cod have paralleled its population growth. Intuitively, it can be argued that the nutrient load increases affecting the groundwater system of the Three Bays Watershed is directly related to the increase in subsurface wastewater disposal systems that accompanied both land development and population growth.

Table 3.7 Percent Population Growth, since 1950 and again from 1990 for the Three Bays Watershed Towns of Barnstable, Sandwich, and Mashpee

Town	1950 – 1960	1950-1970	1950-1980	1950-1990	1950-2000	1990 – 2000	1990 - 2006
Barnstable	28.5	89.3	194.8	291	356	16.7	15.6
Mashpee	98	194	745	1700	2856	64.2	81.9
Sandwich	-14	117	261	541	737	30.6	32.4
TOTAL	20	85	196	235	443	61.6	64

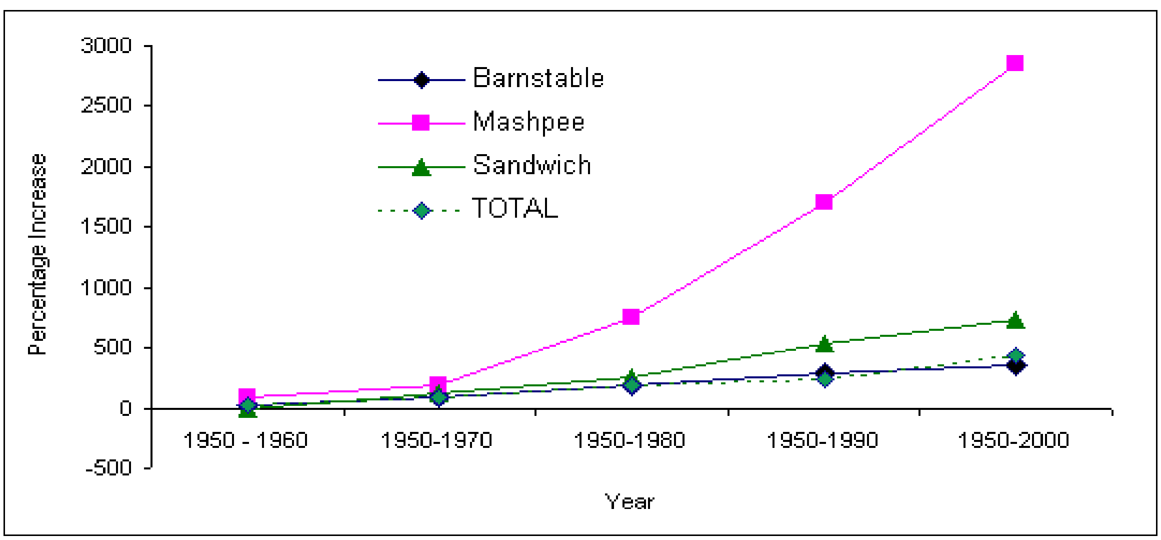


Figure 3.12 Percent Population Increase since 1950 for Three Bays Watershed Towns

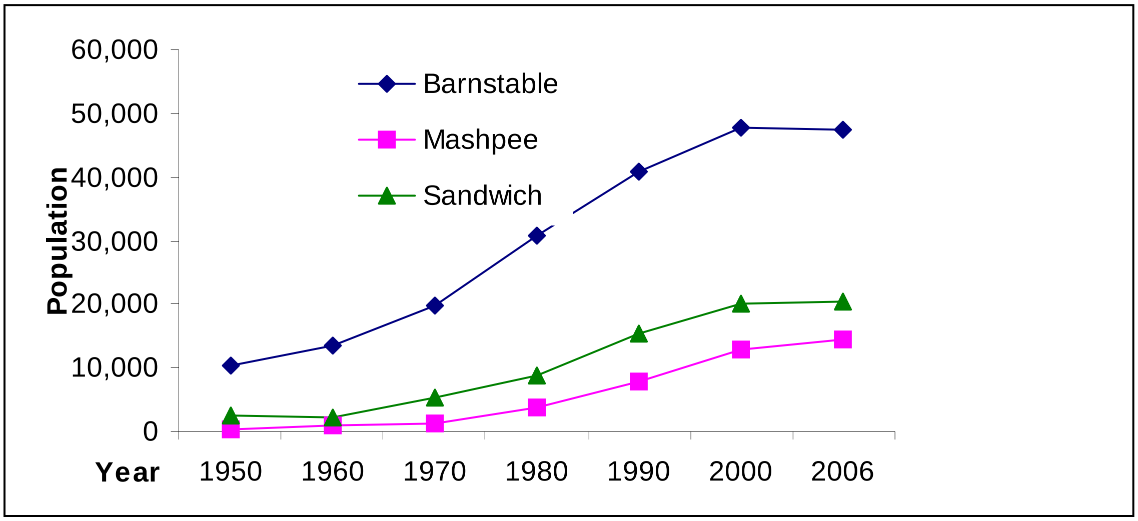


Figure 3.13 Population Growth since 1950 for the Three Bays Watershed Towns

The population of Mashpee and Barnstable has increased markedly since 1950. Of the three towns, Mashpee has undergone the greatest percentage increase (Table 3.7, Figures 3.12) following the 1983 federal court ruling that the Wampanoag Indian tribe was not federally recognized and as such had no legal grounds to reclaim the entire town as tribal land. The town of Barnstable, the largest of Cape Cod's 15 communities, added the most new residents (10,051) from 1980 to 1990 (Figure 3.13) and from 1990 to 1996 gained another 2,750 new residents for a 7% increase to 43,699; the second highest of the 351 Massachusetts municipalities (Franklin had the largest increase). The Town of Sandwich also saw a substantial increase in growth from 1990 to 1996 with a 16% increase from 15,489 to 17,916 - the highest percentage gain among Cape towns. For more information, see the Cape Trends Report, 1998 (http://www.capecodcommission.org/data/trends98.htm).

Based on the data presented in the MEP Three Bays Technical Report (Howes et. al., 2006) the estimated the population of the Three Bays watershed is approximately 13,600 (based 2.41 average household size multiplied by the 5,668 residential parcels in the watershed). Since the completion of the MEP Technical Report in 2004, basing its estimates on 2001 data, the three towns continued to grow. For example, the Town of Mashpee's estimated 2006 population (US Census) outpaced both Sandwich and Barnstable with an increase of 10.79 percent (12,946 to 14,343) from 2001 to 2006 period; while Sandwich grew a modest 1.3 percent (20,238 to 20,508) and Barnstable having a –0.92 percent (from 47,821 to 47,380) (Table 3.7, Figure 3.12).

The significance of these statistics is clear. Title 5 on-site septic systems continue to serve new households with ever increasing nitrogen loads affecting this estuary beyond the 2004 MEP Technical Report estimates. However, in recognition that these increases are inevitable the MEP Technical Report provides an estimate of these future loads under build-out conditions under current zoning for each of the towns sharing this watershed.

3.4.3 Population Density

US Census population density statistics, reported as persons per square mile, are also helpful in assessing land use development because it defines locations within the watershed where the wastewater burden affecting the Three Bays embayments are the greatest. Overall, this increase in population density within the Three Bays, and the wastewater disposal that accompanied this population increase has and continues to play a major role in the observed declines in estuarine habitat quality throughout much of this embayment system.

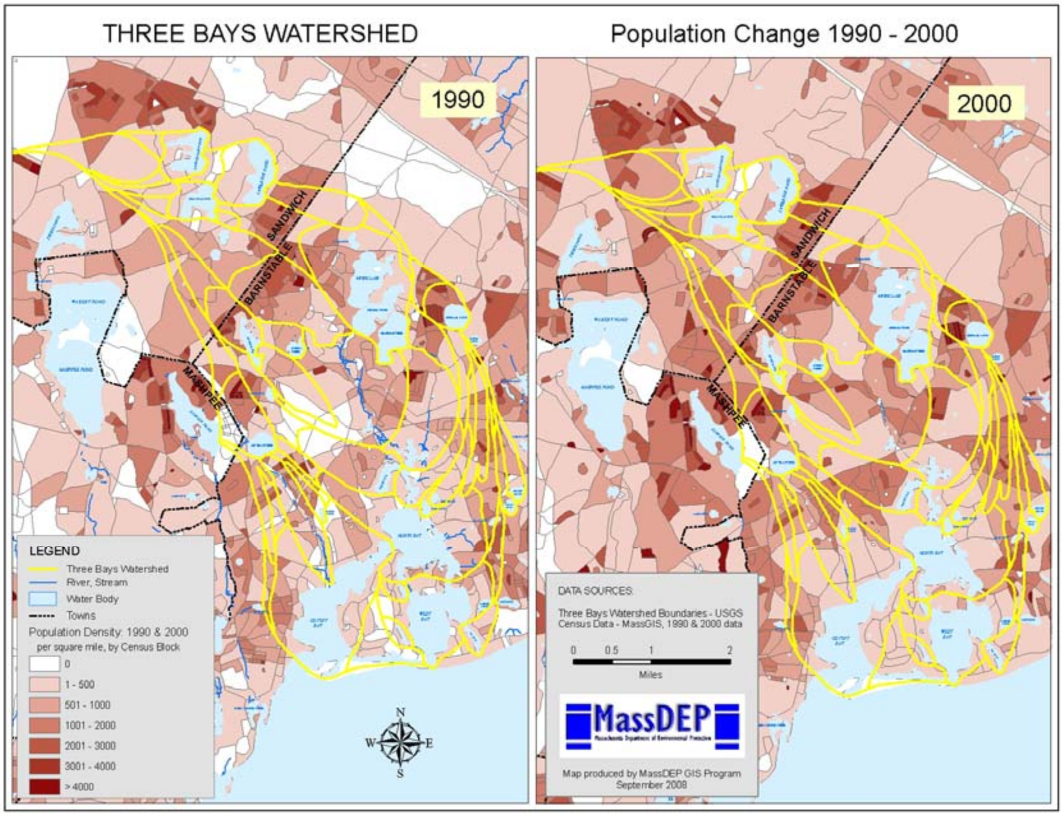


Figure 3.14 Changes in Population Density for the Three Bays Watershed from 1990 to 2000.
(Source: US Census**)**

3.5 Three Bays Pilot Project

3.5.1 Building a Watershed Team

This Pilot Project relied on a team of key local officials and citizens with support from the Cape Cod Commission, MassDEP, and SMAST (Table 3.8). As most of the Three Bays Watershed is located within the borders of the Town of Barnstable, Barnstable town officials took the lead and responsibility for initiating and coordinating much of the planning for the Pilot Project. The DPW's Special Projects Manager coordinated with the DEP Project Manager in all aspects of the project. This was important for the Town as it had been undergoing a townwide nitrogen management plan of its own in conjunction with meeting the TMDL-related nitrogen and bacteria reduction requirements for other embayments within its town borders.

The key players from the Town of Barnstable included members from the Department of Public Works and Growth Management Departments. Other team players included the Three Bays Preservation, Inc. – an environmental advocacy organization, and officials from the Towns of Sandwich and Mashpee. The Town of Sandwich was represented by a member of the selectman appointed Water Quality Advisory

Committee. It was understood that the committee would utilize the nitrogen loads from the MEP Technical Report for deciding other scenarios for the load reductions the three towns would support. Staff from SMAST attended in the early stages of the Pilot to explain the role of the MEP Technical Reports and that the Towns should view the scenario presented within the Report as one of many nitrogen reduction scenarios for reducing nitrogen for the restoration of water quality to the threshold concentration at the designated sentinel station in the Narrows. The team should consider what is feasible for their town and consider other scenarios the Pilot Project would fund for discussion at future meetings. Consulting engineers and Barnstable County staff also attended occasionally or as requested.

Prior to the first meeting in November of 2007, MassDEP had met with key officials in each town to explain the project and as explained in Chapter 1.2.3 requested each town to commit in writing and to provide staff to guide the Pilot Project Team's planning process along.

Table 3.8 Three Bays Watershed Pilot Team

Name	Affiliation
Cambareri,Tom	Cape Cod Commission, Water Resources Program Manager
Counsell, Lindsey	Three Bays Preservation
Daley, Patty	Town of Barnstable, Growth Management Department Director and Wastewater TAC
Eichner, Eduard (former)	Cape Cod Commission, Water Scientist
Ells, Mark	Town of Barnstable, DPW Director and Wastewater TAC
Fudala, Tom	Town of Mashpee, Planning Department Director and Chair of Sewer Commission
Gahagan, Bill	Three Bays Preservation Association
Heller, Judy	Three Bays Preservation Association
Howes, Brian	University of Massachusetts – Dartmouth, SMAST; Director, Coastal Systems Program
Largay, Richard	Three Bays Preservation Association, Board of Directors
Mason, David	Town of Sandwich, Health Agent
McKean, Thomas	Town of Barnstable, Health Department Director
Rask, Susan	Barnstable County Department of Health & Environment
Rowland, Peggy	Three Bays Preservation Association
Saad, Dale	Town of Barnstable, DPW Special Projects Manager and Wastewater TAC
Seymour, Steve	Town of Barnstable, Growth Management Department Engineer and Wastewater TAC
Schwinn, Don	Three Bays Preservation Association
Weeks, Nate	Stearns and Wheler – Town of Barnstable Consultant
Wyle, Ruth	Town of Barnstable, Growth Management Director and Wastewater TAC
Zoto, George	MassDEP, MEP Project Manager, Hyannis
Zylich, Michael	Town of Sandwich, Water Quality Advisory Committee, member

3.5.2 Team Meetings

The Pilot Project Team met roughly monthly when the project began in November of 2007

Team meetings focused on:

- In-depth understanding of the MEP Technical Report and use of the Linked Model.
- Review of the nitrogen reduction scenario described in Chapter VIII.3 of the MEP Technical Report
- Now that the TMDLs are developed, how should they be applied?

- How should responsibilities be assigned for N reductions in shared watersheds?
- Three model runs were proposed by the Town of Barnstable TAC and MassDEP as scenarios to determine if the nitrogen reductions proposed by sewering different locations or sewersheds within the Town of Barnstable would achieve the threshold concentration at the sentinel station in the Three Bays.
- Discussion of local and state management and regulatory issues.

As 87 percent of the land area of the watershed resided within the town limits of Barnstable, it was clear that Barnstable would take the lead with the planning and implementation of the nitrogen reductions within the watershed. Regardless, the towns Sandwich and Mashpee also have a responsibility for the load reductions from their town borders. However, the town of Mashpee with less than one percent of the land area within this watershed did not attend meetings because their own CWMP planning was underway for the Popponesset and Waquoit Watersheds, of which they were responsible for most of the nitrogen reductions (greater than 60 percent) from those watersheds.

Prior to the first scheduled Pilot Project meeting, the Town Manager, DPW Director, DPW Special Projects Manager, Executive Director of the Three Bays Preservation, and community members residing in the Three Bays Watershed met to support the project and its goal.

The November 2007 Pilot Project Team meeting was also attended by staff from SMAST and the Cape Cod Commission to present an overview of the MEP. Dr. Howes of SMAST introduced Pilot Team members to the MEP approach for data collection, quantification of nitrogen loads, and the environmental "what if" inputs to the MEP Linked Model for use in calculating scenario run outcomes for reducing watershed nitrogen loads and/or its allocation by town.

Engineering, regulatory, and planning staff from other town offices also attended whenever those meetings addressed technical and policy issues within their area of expertise and responsibility.

During the brief tenure of this Case Study, the Three Bays Pilot Project focused its energies on the identification of potential locations for sewering, treatment, and disposal; including the estimated wastewater flows.

Since the Three Bays Pilot Project engaged the same team members as the Popponesset Pilot Project Team, there was no need for a detailed discussion of the MEP approach, the interpretation of the MEP Technical Reports or how this data could be used to address the nitrogen-load reductions the three towns would be sharing responsibility to reduce. The focus was on the type of treatment, where, and how much to sewer within the watershed to achieve the nitrogen threshold concentration at the Cotuit Narrows sentinel station. Other issues addressed, to a limited degree, included:

- Wastewater Loads: Treatment Plants and Onsite Systems
- Recharge of treated effluent into the Three Bays Watershed
- Pollution Prevention: Fertilizer Management, Water Reuse and Conservation, and Stormwater Management
- Enhanced Natural Attenuation at the Mill Pond located at Rt. 149 and Rt. 28
- Moving water from one coastal watershed to another.
- Outreach to elected officials

3.5.3 SMAST Linked Model Runs

3.5.3.1 Barnstable TAC Scenario Run Options

The areas for sewering (also known as a "sewershed") and the sites for treating and discharging the treated flows were designated by the Town of Barnstable's technical staff (TAC) and MassDEP utilizing the data presented in the April 2006 Three Bays Tech Report (Howes et. al., 2006; http://www.oceanscience.net/estuaries/3Bays.htm). A "sewershed" is an engineering planning area defined by the roadway network, the location of pump stations, other infrastructure and the intensity of development for the proposed sewering. Their proposed scenarios for sewering (Table 3.9) were submitted to SMAST to model to determine if any of the proposed nitrogen reductions would achieve the nitrogen threshold concentration at the Cotuit Narrows sentinel station. These scenarios examined the nitrogen reduction potential of sewering three locations within the watershed using at two sites for treatment and disposal - an existing treatment facility at a shopping plaza in Cotuit (Option A), and the construction of a small treatment plant on land abutting the Barnstable Transfer Station (Option B):

Please refer to Figure 3.15 to visualize the extent of the sewersheds (crosshatched areas in several of the subwatersheds) and the locations proposed for discharge of the treated wastewater.

Scenario 1: Two treatment facilities and two discharge areas

> There are two (2) possible sites known as Discharge Areas "A" and "B".
> (Option A) The first discharge site is Area "A" located in Prince Cove GT10 near the Cotuit Shopping Plaza on Route 28 (Assessors map: 040 parcel: 003T00 & C00).
>
> (Option B) The second site is Discharge Area "B" in Middle Marstons Mills LT10 next to the Barnstable Transfer Station (Assessors map: 099 parcel: 028-001).

Scenario 2: One treatment facility and discharge area

> All effluent will be discharged at Discharge Area "B" in Middle Marstons Mills LT10, the land next to the Barnstable Transfer Station (map: 099 parcel: 028-001).

Scenario 3: Nutrient sharing between towns

> Determine the Nitrogen Load to the Three Bays Estuary originating from each of the 3 towns comprising the contributing area, Barnstable, Mashpee, Sandwich (See Table 3.10).

The output of the SMAST scenario runs is fully described in the SMAST Technical Memo (Howes, B. et. al., 2007) (Appendix N). The restoration goals for these scenario runs were based on removing sufficient N loads, primarily from septic systems, to support infaunal habitat in North Bay and eel grass habitat in both East and West Bay. The proposed reductions for the identified subwatersheds were insufficient to restore the water quality at the sentinel station location in the bay. As listed below, the resultant nitrogen concentrations at the sentinel location for each scenario were above the restoration target of 0.38 mg N/L.

> Scenario 1 - 0.454 mg/L
> Scenario 2 - 0.448 mg/L
> Scenario 3 – described in section 3.5.3.2 "Fair Share"

Figure 3.15 Sewershed Locations Proposed for Septic Load Reductions in the Three Bays Watershed

Table 3.9 Three SMAST Scenarios for reducing nitrogen in the Three Bays Watershed

Scenario 1. Two Treatment Facilities (5 mg/l N) And Discharge Areas.	
Discharge Area "A" located in Prince Cove GT10	
Sub-embayment	Percent Treated and Discharged to Area "A"
Prince Cove LT10	100
North Bay GT10W	100
North Bay LT10	20
Upper Marstons Mills River	10
Prince Cove GT10	5
Lower Marstons Mills River LT10	20
Discharge Area "B" located in Middle Marstons Mills LT10	
Sub-embayment	Percent Treated and Discharged to Area "B"
Upper Marstons Mills River	90
Lower Marstons Mills River LT10	55
Lower Marstons Mills River GT10	40
Middle Marstons Mills River LT10	80
Bog Pond LT10	60
Bog Pond GT10	90
COMM Davis/Arena/McShane Wells	90
North Bay GT10E	30
Joshua Pond GT10	90
Joshua Pond LT10	60
Micah Pond	95
Scenario 2. One Treatment Facility (5 mg/l N) And Discharge Area.	
Discharge Area "B" located in Middle Marstons Mills LT10	
Sub-embayment	Percent Treated and Discharged to Area "B"
Prince Cove LT10	100
North Bay GT10W	100
North Bay LT10	20
Upper Marstons Mills River	100
Prince Cove GT10	5
Lower Marstons Mills River LT10	75
Lower Marstons Mills River GT10	40
Middle Marstons Mills River LT10	80
Bog Pond LT10	60
Bog Pond GT10	90
COMM Davis/Arena/McShane Wells	90
North Bay GT10E	30
Joshua Pond GT10	90
Joshua Pond LT10	60
Micah Pond	95
Scenario 3. Nutrient Sharing between Towns.	
Run the amount of nitrogen that is in the Three Bays watershed that originates in Sandwich and Mashpee.	
Having those numbers will give us a basis to begin to think about nutrient trading with our neighbor towns.	

3.5.3.2 Scenario Run Results and Proposed Future Options

It was also learned that eighty two percent of the nitrogen loads that affected this embayment system occur within a 10 year time of travel from their discharge in the Three Bays headwaters.

Additional MEP model runs are under consideration as part of the town's CWMP to identify other locations within the Three Bays watershed for sewering. A town-wide assessment of sewering needs will also address the cost and benefit of using the existing centralized treatment facility in the Village of Hyannis. Also under consideration is the option of assisting the Town of Mashpee with its costs for the Popponesset, if they would sewer portions of the Village of Cotuit as part of its CWMP to sewer the Popponesset Watershed.

If use of the centralized treatment facility in Hyannis is considered as the most cost and environmentally effective solution to reduce the watershed loads, the Town and ultimately MassDEP will need to decide if returning this treated wastewater to its Three Bay watershed source location is necessary for water balance considerations.

The following questions are under consideration for future nitrogen-reduction scenario runs:

- Would a 100 percent reduction of the nitrogen load in the subwatersheds that abut the North Bay and a 20 percent in those abutting Cotuit and West Bays achieve the threshold concentration at the sentinel location?
- The assumption that the nitrogen load reductions that effectively restore water quality is dependent on maintenance dredging of the inlets sufficient to sustain current levels of flushing with Nantucket Sound.
- Would the sewering of the subwatersheds with the greatest population densities (near Route 28) be sufficient to restore water quality?
- Groundwater is discharged to Mill Pond (at Rt 149/Rt 28) at 5 million gallons/day. At that rate, the Town should explore the potential of using this site to enhance the reduction of nitrogen by natural attenuation by increasing the pond's depth for improved storage and treatment.
- Would 100% sewering of the Three Bays watershed and the discharge of the treated effluent within the watershed at location "B" be sufficient to meet the threshold concentration at the sentinel station? The analysis of this scenario is underway and results should be available in October 2008.

"Fair Share"

The third scenario was geared to identify the nitrogen loads that originate within each of three towns comprising the contributing area of the watershed. Having these town-by-town loads provided to the Pilot Project Team could be the basis for discussing nutrient trading options.

At the Pilot Project Team's first meeting, the outcome of the third scenario was presented by the Cape Cod Commission; which in essence highlights the "fair share" concept that was championed by the Popponesset Pilot Project team (Chapter 2.8.4 of this report).

The data presented by the Cape Cod Commission (Appendix N), as shown in Tables 3.10, 3.12 and Figure 3.16, defined the town-specific attenuated and unattenuated loads for existing land uses and those anticipated in the future, at build-out, under current zoning. This information was offered to spur discussion concerning the allocation of the nitrogen reductions each town would address in its CWMP and ultimately for use in deciding each town's financial responsibility. When decided, the allocation of loads between towns could be a nitrogen trading option to help reduce the assigned maximum watershed load from each town and which would not increase in the future after the load reductions were successful in restoring water quality at the sentinel location in the Bay. To help understand how the complexity of assigning a load reduction, Figure 3.16 was prepared to further define the town-specific nitrogen loads by subwatershed as attenuated and unattenuated nitrogen load for existing and future built-out conditions. However, as explained earlier, the reductions in nitrogen loads will vary within each subwatershed because the natural attenuation factors are not the same. In some cases, due to the presence or absence of wetlands and pond systems, there may be a significant net reduction in the load while in other subwatersheds there may be none.

Table 3.11 displays the variability in subwatershed controllable loads (septic, fertilizer, stormwater runoff) and the percentage of the load that is needed for reduction to restore water quality at the sentinel location. When viewed in conjunction with Table 3.12, it becomes clear which of the three towns have the greatest loads for reduction. For example, Table 3.12 identifies an 84% nitrogen reduction is required from the Prince Cove Channel and of this load 100% of it originates from the Town of Barnstable. Also, a 98% reduction is required from North Bay and of this reduction 100% of it originates in the Town of Barnstable.

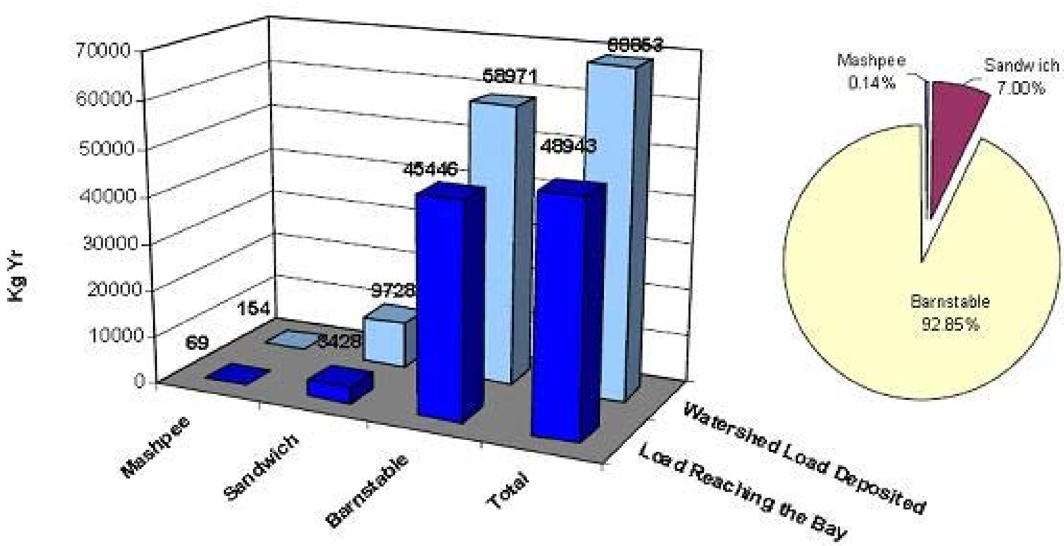


Figure 3.16 Nitrogen Loads from the three towns under existing conditions described as (a) the unattenuated loads deposited to the watershed, (b) the attenuated load that reaches the Bay and (c) a pie chart that defines the percent of attenuated load contributed by each town.

Table 3.10 Unattenuated load deposited to watershed and attenuated nitrogen load that reaches the Bay from each of the three towns sharing the Three Bays Watershed (Source: Cape Cod Commission Technical Memo, see Appendix N).

			Nitrogen Load (kg/y)							
			Existing				Built -out			
Town	Area (acres)		Unattenuated		Attenuated		Unattenuated		Attenuated	
Barnstable	9418	87%	58971	86%	45446	93%	66481	84%	50959	92%
Sandwich	1464	13%	9728	14%	3428	7%	12468	16%	4500	8%
Mashpee	85	0%	154	0%	69	0%	277	0%	124	0%
Total	10882	100%	68853	100%	48943	100%	79226	100%	55583	100%

Table 3.11 Percent reductions of controllable watershed loads that are required to restore water quality to the threshold concentration at the sentinel station

Sub-embayments	Present Controllable Sub-Watershed Load [1] (kg/day)	Target Threshold Sub-Watershed Load [2] (kg/day)	Percent controllable sub-watershed reductions needed to achieve threshold load levels
Cotuit Bay	25.74	22.34	13 %
West Bay	19.068	15.97	16 %
Seapuit River	3.767	3.77	0 %
North Bay	29.447	4.47	84 %
Prince Cove	35.173	17.89	49 %
Warren Cove	12.027	5.05	50 %
Prince Cove Channel	5.537	0.77	86 %

[1] Composed of combined fertilizer, runoff, WWTF effluent, and septic system loadings
[2] Target threshold watershed load is the load from the watershed needed to meet the embayment threshold N concentration of 0.38 mg/L.

Barnstable Officials have stated that their town-wide wastewater management planning would address the necessary loads from the Three Bays watershed for the purpose of achieving the nitrogen threshold concentration at the sentinel location. Inter-municipal memoranda of understanding would be pursued with the towns of Sandwich and Mashpee to cost share the sewering of the watershed for the purpose of allocating load reductions by town that are the most cost effective for achieving the nitrogen threshold concentration at the sentinel location in the estuary.

Dr. Howes cautioned the towns in using this "fair share" approach for apportioning loads from land held in conservation and other open space protected lands (Zone I's to public water supply wells) for each town; suggesting they may want to exclude the acreage from these protected lands from their calculation as they are unlikely to generate anthropogenic sources of nitrogen loading.

Table 3.12 Attenuated and unattenuated load by sub-watershed, under existing and build-out conditions, for the Towns of Barnstable, Sandwich, and Mashpee

TMDL Segment	N Load (kg/y)															
	Existing Unattenuated				Existing Attenuated				Buildout Unattenuated				Buildout Attenuated			
	BAR	SAN	MAS	TOTAL	BAR	SAN	MAS	TOTAL	BAR	SAN	MAS	TOTAL	BAR	SAN	MAS	TOTAL
Cotuit Bay	10712	1175	134	12020	8971	511	59	9541	12258	1437	240	13935	10087	625	105	10817
West Bay	7185	0	0	7185	6960	0	0	6960	7557	0	0	7557	7328	0	0	7328
Seapuit River	1375	0	0	1375	1375	0	0	1375	1645	0	0	1645	1645	0	0	1645
North Bay	11475	179	20	11673	10648	89	10	10748	12629	219	36	12884	11688	109	18	11815
Prince Cove	4636	882	0	5519	4420	457	0	4877	5190	1134	0	6324	4964	583	0	5547
Warren Cove	21380	7492	0	28872	11051	2370	0	13421	24601	9678	0	34279	12851	3183	0	16034
Prince Cove Channel	2208	0	0	2208	2021	0	0	2021	2600	0	0	2600	2396	0	0	2396
TOTAL	58971	9728	154	68853	45446	3428	69	48943	66481	12468	277	79225	50959	4500	124	55583

TMDL Segment	N Load (%)															
	Existing Unattenuated				Existing Attenuated				Buildout Unattenuated				Buildout Attenuated			
	BAR	SAN	MAS	TOTAL	BAR	SAN	MAS	TOTAL	BAR	SAN	MAS	TOTAL	BAR	SAN	MAS	TOTAL
Cotuit Bay	89%	10%	1%	100%	94%	5%	1%	100%	88%	10%	2%	100%	93%	6%	1%	100%
West Bay	100%	0%	0%	100%	100%	0%	0%	100%	100%	0%	0%	100%	100%	0%	0%	100%
Seapuit River	100%	0%	0%	100%	100%	0%	0%	100%	100%	0%	0%	100%	100%	0%	0%	100%
North Bay	98%	2%	0%	100%	99%	1%	0%	100%	98%	2%	0%	100%	99%	1%	0%	100%
Prince Cove	84%	16%	0%	100%	91%	9%	0%	100%	82%	18%	0%	100%	89%	11%	0%	100%
Warren Cove	74%	26%	0%	100%	82%	18%	0%	100%	72%	28%	0%	100%	80%	20%	0%	100%
Prince Cove Channel	100%	0%	0%	100%	100%	0%	0%	100%	100%	0%	0%	100%	100%	0%	0%	100%
TOTAL	86%	14%	0%	100%	93%	7%	0%	100%	84%	16%	0%	100%	92%	8%	0%	100%

3.5.3.2 Inter-municipal Sharing of Wastewater Treatment Capacity

Barnstable continues its wastewater/nutrient management planning with the Towns of Sandwich and Mashpee as they continue to express a desire for a shared responsibility to reduce the nitrogen loads from their portions in both the Three Bays and Popponesset Bays Watersheds. Current thinking, while not official, is that this would first require the support of Barnstable's elected leadership who must approve all appropriations by the town. Plans are currently underway in the three towns to educate both the leadership of each town concerning nitrogen pollution, its impacts to affected subembayments, what was learned from the Pilot Project, and proposals for joint, intermunicipal collaboration concerning where sewering would be the most cost effective in achieving the desired results in the estuary for the three towns. For example, it may be beneficial for Barnstable to coordinate with the Town of Mashpee in its CWMP to address the nitrogen reductions from the village of Cotuit (the southwestern and western most portion of the Town) by paying the Town of Mashpee to sewer these areas because Mashpee's plan for sewering includes properties abutting Barnstable. A similar cost saving arrangement is currently under consideration with the Town of Yarmouth, where it would be more cost effective to reduce the nitrogen loads from the village of West Yarmouth by paying Barnstable to extend its sewer mains to those properties that abut the Village of Hyannis where the waterwater treatment facility is located.

This arrangement also benefits the Town of Barnstable because the newest expansion of its wastewater treatment facility in the village of Hyannis is expected to be completed in 2009, at a time when sufficient treatment capacity and flows are expected from West Yarmouth to help defray the cost of the newly expanded facility.

3.5.4 Proposals for Sewering the Three Bays Watershed

3.5.4.1 Inter-municipal Planning

The three towns have discussed on an unofficial basis the possibility of joint planning for the nitrogen reductions they are responsible for reducing for TMDL compliance purposes within the watersheds they share. As discussed earlier, the towns of Barnstable and Mashpee are both engaged in the preparation of a CWMP that addresses the load reductions from the sub-watersheds within their town boundaries. However, while the Town of Sandwich has expressed an interest in inter-municipal planning, the Town is currently unable to cover the costs of hiring a consultant to address the nitrogen loads within its town borders. As discussed in the Popponesset Case Study, Sandwich succeeded in taking its first step when the selectmen understood the importance of addressing the impacts of the town's nitrogen loads to the Popponesset and Three Bays Embayments when the Board appointed the Water Quality Advisory Committee. This advisory committee includes representation from the Conservation Commission, Planning Board, Public Works, Board of Health, and Board of Selectmen. How soon Sandwich is able to collaborate with its neighbors will depend on its ability to hire a consultant through funding expected resulting from a NRD settlement penalty for contamination of the town's groundwater source of drinking water.

3.5.4.2 Actions Completed and Proposals for Follow-Up by the Town of Barnstable

Those actions completed and underway by the Town of Barnstable are numerous. These include a town-wide CWMP that addresses the nitrogen and bacteria reductions as defined in the MEP technical and TMDL reports. Plans are also underway to upgrade it's wastewater treatment facility in the Village of Hyannis and to expand its collection system westward toward Mashpee for sewering the Three Bays and possibly the Popponesset Watershed; anticipating some actions that would be mutually beneficial to each community.

Treatment Upgrade and Sewer Expansion: To date, $1.2M has been appropriated for the design of the sewer expansion plan and $8 M to upgrade the treatment capacity at the Hyannis Water Pollution Control Facility (WPCF). The preliminary design for the first phase of the sewer expansion is currently undergoing review. The expansion is described in Barnstable's' Comprehensive Wastewater Facilities Plan that was approved by MEPA and the Cape Cod Commission in October 2007. The Comprehensive Sewer Expansion Plan is undergoing development with a preliminary design layout of sewer main and pump station locations westward of the Hyannis WPCF to Areas of Concern (AOC) in the Village of Centerville (including Lake Wequaquet and Long Pond areas). When completed, this will assure an efficient expansion of the sewer system while maximizing use of existing mains and pump stations. The preliminary design plan also includes coverage for other AOC's. The Hyannis WPCF increase in treatment and discharge capacity to 4.2 MGD is expected for completion during the winter 2009.

As part of its planning, Barnstable officials are considering the transfer of wastewater flows outside the Three Bays watershed for treatment at the Hyannis WPCF. In anticipation of the need for the CWMP to address water balance, an opinion may be required from MassDEP concerning the Commonwealth's position on transferring water from one coastal groundwatershed to another – all within the confines of the Sagamore lens. Will the Cape's groundwater lens characteristic with a span of many square miles have the same need to restore water balance as required by a CWMP for an off Cape surface-drainage watershed? In other words, would water transfer between coastal groundwatersheds within the Sagamore Lens, over time, have local groundwater elevation impacts from where it is received? This is one issue MassDEP will need to address in the future as part of regional planning for sewering one or more nitrogen-sensitive groundwatersheds with TMDLs.

In addition, the transfer of wastewater outside the groundwatershed of origin for disposal, reuse, and or groundwater recharge, at some point will require guidance from MassDEP concerning the permitting requirements under the Wetlands Protection Act; especially the use of wetlands for the natural attenuation of nitrogen loads and water recharge. MassDEP has begun the process of defining the capacity of wetland systems to treat wastewater via natural attenuation when the Department funded the Woods Hole Group and Teal Associates to perform a literature review on this subject (see Executive Summary, Appendix J). While a decision has not been made concerning the use of natural attenuation as a nitrogen treatment option, MassDEP has made the commitment to address this through regulatory policy or regulations as a potential low cost treatment option for towns to consider.

Promoting the need to sewer continues to engage public discussion in Barnstable. In addition, a workshop is planned with the Town Council, its elected leadership, to inform them on the status of the preliminary design and need to proceed with the expansion of its sewering to address the town's nitrogen-sensitive watersheds.

The Town anticipates adopting a sewer neutral policy in the Local Comprehensive Plan (LCP) and passing appropriate ordinances/regulations to ensure that existing development expansion is limited to allowed on-site Title 5 flows. The Barnstable Board of Health has adopted several regulations that deal with sewer connections and I/A systems, which can be viewed on the Town's web site (see Appendices T and U).

Mill Pond Dredging/ Nitrogen Attenuation Proposal: Joint plans to increase natural attenuation of the fresh water system with support by another town (Sandwich) are under consideration to help defray the cost of a proposed demonstration project. Increasing the depth of this shallow pond, through dredging using the county dredge, would be studied to determine if natural attenuation would further reduce the nitrogen load passing through this wetlands system. The concept is based on the premise that a great deal of the groundwater from headwater locations from the Marstons Mills River passes through this pond. By increasing the limited storage and retention capacity of this shallow pond – currently with a sediment depth of 12 feet and 3 feet of open water, it is hoped the project would demonstrate further attenuation of nitrogen than is possible as a shallow pond.

Streambeds/upland wetlands for multiple uses: Ideas that should be pursued for future consideration as low tech, innovative, low-cost options for reducing nitrogen loads, include:

- Disposal of Treated Wastewater: CWMPs should explore the possibility of siting inland wastewater disposal sites that would take advantage of natural attenuation to "polish" treated wastewater discharges with concentrations at 3 – 4 mg/L N to lower concentrations prior to its discharge to the estuary.

- Restoring the streambed from Hamlin Pond, near Cape Cod Resources location. With NOAA funding support this streambed, which has been filled in by Cape Cod Resources, could be restored to full function with wetland habitat function and nitrogen attenuation while at the same time be restored as habitat for anadromous fish.

3.5.5 Pilot Project Team Issues and Suggestions

CWMP related issues that require MassDEP policy

- Transferring water between coastal groundwatersheds. What is allowed for water transfer between different coastal groundwatersheds? Need more information on how to handle the watershed flows; wastewater pulled out of one watershed vs. treated water recharged into another watershed. Must treated wastewater be returned to the watershed it was generated from? Can wastewater be treated in one town and recharged in another town?
- Permitting to change wetlands types for use in natural attenuation and recharge of water. Can a CWMP rely on the use of natural attenuation as a nitrogen treatment option? How much of existing, natural wetland systems be manipulated to enhance natural attenuation? What are the necessary procedures and permitting requirements to change one type of a wetland to another (*i.e.* old abandoned cranberry bog changed to open water pond system)?
- What is the timeline for towns that are working jointly on a shared watershed when they are at very different stages of planning and funding? Considering these differences, what are MassDEPs expectations of a timeline for the development of CWMP implementation plans?
- Funded mandates

Obstacles that must be overcome to address watershed-based TMDL implementation

- It must be clear to all towns sharing a watershed that they must work together and that none of the towns is without some responsibility to restore the embayment habitat.
- Funding of projects and the cost of sewering
- Locating sites for wastewater treatment and effluent discharge.

Role of community-based outreach and planning in the implementation of proposed wastewater mitigation measures

- Funding is the key issue. If the towns cannot convince its residents that CWMP implementation is a needed program, you will not receive the needed money to proceed. Must win over Town Council to support sewering projects and other nutrient treatment programs (NDA, stormwater/road work, etc.).

Citizen Advisory Committee (CAC) can be the bridge between the town's technical staff and the community when proposing projects.

Lessons Learned to Share with Other Coastal Watershed Communities

- If a high percentage of the watershed and waterbody is in one community then the other towns that share the watershed/waterbody often look at the problem as not theirs. As the other towns look at their other watersheds, they reconsider and understand that we are all in this together.
- We need to use terms which are more familiar to town government (ex .the use of MOUs is more familiar and user friendly).
- It is a long journey that each town must undertake and with the help of other towns in the watershed. We can make the journey together and hopefully a more cost-effective, environmentally-sound outcome will be achieved, with a restored habitat that we can all enjoy and profit from.
- Community-based outreach and planning is critical to funding the implementation of proposed CWMP measures. If the towns cannot convince people that implementation is a needed program then you will not receive the needed money to proceed. Must win over elected officials to support sewering projects and other nutrient treatment programs (NDA, stormwater/road work, etc.). A Citizen Advisory Committee (CAC) can be the bridge between the town's technical staff and the community when proposing projects for funding.

Chapter 4: Pleasant Bay Watershed

Figure 4.1 Aerial views Pleasant Bay displaying its single inlet (top) and the breach to its barrier beach that resulted in a second inlet on April 19, 2007.
(Photo provided by the Town of Chatham, Kelsey-Kennard air view, www.capecodphotos.com)

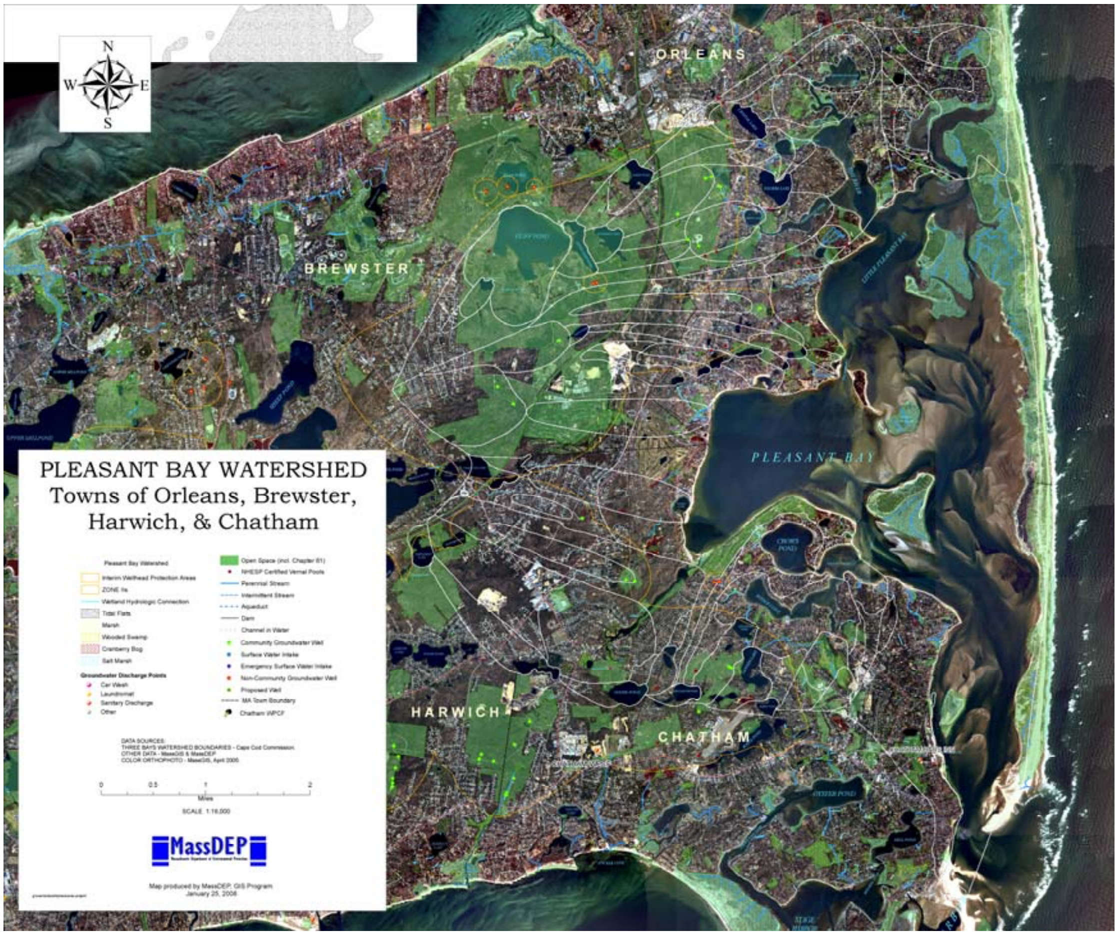


Figure 4.2 Aerial photo of the Pleasant Bay Watershed and its embayments showing the southern inlet that impeded tidal exchange with the Atlantic Ocean, prior to April 19, 2007 when a new second inlet was formed on the barrier beach.

4.1 Pleasant Bay Watershed Facts

Key Feature	TMDL implementation in a tidal estuary
Project Name	Pleasant Bay Watershed, Inter-municipal Watershed TMDL Implementation
Scope/Size:	Watershed area: 33.75 square miles (ca. 21,599.72 acres); approximately 9 miles north to south and just over 3 miles east to west
Land Type	38% residential (predominantly single family homes); 37% government building, lands and roads; 12% undeveloped, 5% golf/recreational; 3% commercial/mixed use; 1% agricultural
Pollutant	Nitrogen
Wastewater Infrastructure	A centralized wastewater treatment facility services a portion of the Pleasant Bay Watershed. The towns of Orleans, Brewster, and Harwich are without municipal sewer; Orleans hosts a regional septage treatment plant; approximately 5 private sewage treatment plants; most properties with residential on-site wastewater disposal systems.
Hydrology	The Pleasant Bay system consists of 19 TMDL sub-embayments (Meetinghouse Pond , The River-upper, The River-Lower, Lonnies Pond, Areys Pond, Namequoit River, Paw Wah Pond, Pochet Neck, Little Pleasant Bay, Quanset Pond, Round Cove, Muddy Creek Upper, Muddy Creek Lower, Pleasant Bay, Ryders Cove, Frost Fish Creek, Crows Pond, Bassing Harbor, and Chatham Harbor. Currently this hydrologically active and dynamic embayment system exchanges tidal water with Nantucket Sound to the South and the Atlantic Ocean to the east through two inlets. (Figure 4.1)*
TMDL Development	NPS subsurface, nitrogen discharges primarily from residential on-site septic systems and secondarily from fertilizer use
Data Sources	Towns of Chatham, Orleans, Harwich, and Brewster; Cape Cod Commission; Massachusetts Department of Environmental Protection (MassDEP); University of Massachusetts at Dartmouth -School of Marine Science Technology (SMAST)
Data Mechanisms	Water quality monitoring results, watershed/parcel specific defined estimates of nitrogen loading based on drinking water use records, USGS delineation of groundwatersheds, and MEP Linked Watershed-Estuary Nitrogen Management Model (Linked Model) for calculating load thresholds.
Monitoring Plan	An on-going Citizens Water Quality Monitoring Program has trained and involved more than 150 citizen volunteers from the Chatham Water Watchers, Orleans Water Quality Task Force, and the Towns of Harwich and Brewster.
Control Measures	Since 1998, the Pleasant Bay Alliance has been engaged for the protection of Pleasant Bay through the development of a state approved, renewable 5-year watershed-wide Resource Management Plan with official representation from the towns sharing this watershed. The Alliance convenes a work group with representation from all four towns and regional and state agencies to facilitate regional collaboration to implement the TMDLs. All four towns are in the process of addressing watershed nutrient loads. In 2001, the Town of Chatham initiated comprehensive wastewater planning (CWMP) to reduce the nitrogen loads from its portion of the Pleasant Bay watershed. The Draft CWMP, approved in June 2008, when carried out will result in the sewering of most properties over a period of 30 years. Orleans and Harwich are presently developing CWMPs. Brewster is in an earlier stage of addressing nutrient loading. In addition, each town has or is in the process of adopting local regulations to manage nutrient loading.

4.2 The Pleasant Bay Watershed

4.2.1 General Description

The Pleasant Bay watershed and embayment system is shared with the towns of Brewster, Chatham, Harwich, and Orleans at the southeastern edge of Cape Cod, Massachusetts. Nearly three quarters of the watershed area lies within the towns of Orleans and Chatham and less in the towns of Brewster and Harwich (Table 4.1). The watershed drainage area consists of 20,680 acres and 21 square miles and slightly over 9 miles north and south and just over 3 miles east and west. This regional resource now has 2 openings in the barrier beach that separates it from the Atlantic Ocean located to the east.

The 19 sub-embayments, shown in Figure 4.2, vary in size and hydraulic complexity, characterized by varying rates of tidal flushing, shallow depths and heavily developed sub-watersheds. They are: Meetinghouse Pond, Lonnies Pond, Areys Pond, The River (upper and lower), Paw Wah Pond, Quanset Pond, Round Cove, Muddy Creek (upper and lower), Ryders Cove, Crows Pond, Bassings Harbor, Frost Fish Creek, Pochet Neck, Little Pleasant Bay, Pleasant Bay and Chatham Harbor. The 3 major sub-watersheds, having the largest contributing land area to the estuary are Little Pleasant Bay, Pleasant Bay and Chatham Harbor. This dynamic embayment system exchanges tidal flow with the Atlantic Ocean through two inlets created on Nauset Beach, the northern breach was created in 2007, the southern breach in 1987. Freshwater enters the system primarily through 3 surface water discharges into Paw Wah Pond, Lonnies Pond and Tar Kiln Marsh, as well as through direct groundwater discharges (Figures 4.2 and 4.3).

Table 4.1 Pleasant Bay Watershed - Area by Town

TOWN	Town Area within Pleasant Watershed *		
	Acres	**Square Miles**	**Percent**
Brewster	3,529.82	5.52	16.34%
Chatham	6,458.67	10.09	29.90%
Harwich	2,789.30	4.36	12.91%
Orleans	8,821.93	13.78	40.84%
Total	21,599.72	33.75	100.00%

* Area includes all water, including estuarine

Due to its extraordinary natural resources, the Conservation Commissions, Boards of Selectmen, and Planning Boards from all four towns of Brewster, Chatham, Harwich, and Orleans nominated Pleasant Bay as an Area of Critical Environmental Concern (ACEC). On March 20, 1987, Pleasant Bay's nomination was designated by the state as an ACEC In 2002, the state's Natural Heritage and Endangered Species Program (NHESP) designated approximately 7,425 acres or 80% of this watershed as a core habitat in its BioMap Project (http://www.mass.gov/dfwele/dfw/nhesp/nhbiomap.htm), which highlights areas in Massachusetts with high biodiversity and most in need of protection. Today this resource enjoys all the protections provided by the Commonwealth of Massachusetts. The diverse and relatively unaltered habitats of this ACEC provide feeding, spawning, and nursery grounds for numerous shellfish, finfish, amphibians, reptiles, birds, and mammals (see: http://www.mass.gov/dcr/stewardship/acec/acecs/descriptions/PleasantBay.pdf).

Other important habitats include its islands, salt and freshwater ponds, rivers, bays, and barrier beaches. These areas provide flood control, storm damage prevention, improved water quality, wildlife habitat, and recreation opportunities to surrounding communities. The state-approved Pleasant Bay Resource Management Plan (1998) , Plan Updates (2003 and 2008), and Guidelines and Performance Standards for Docks and Piers in Pleasant Bay (2001) were prepared and coordinated by the Pleasant Bay Resource

Management Alliance; the Pilot Project partner for this Case Study. These documents are used by the four watershed towns as a framework to protect the natural resources of this embayment system.

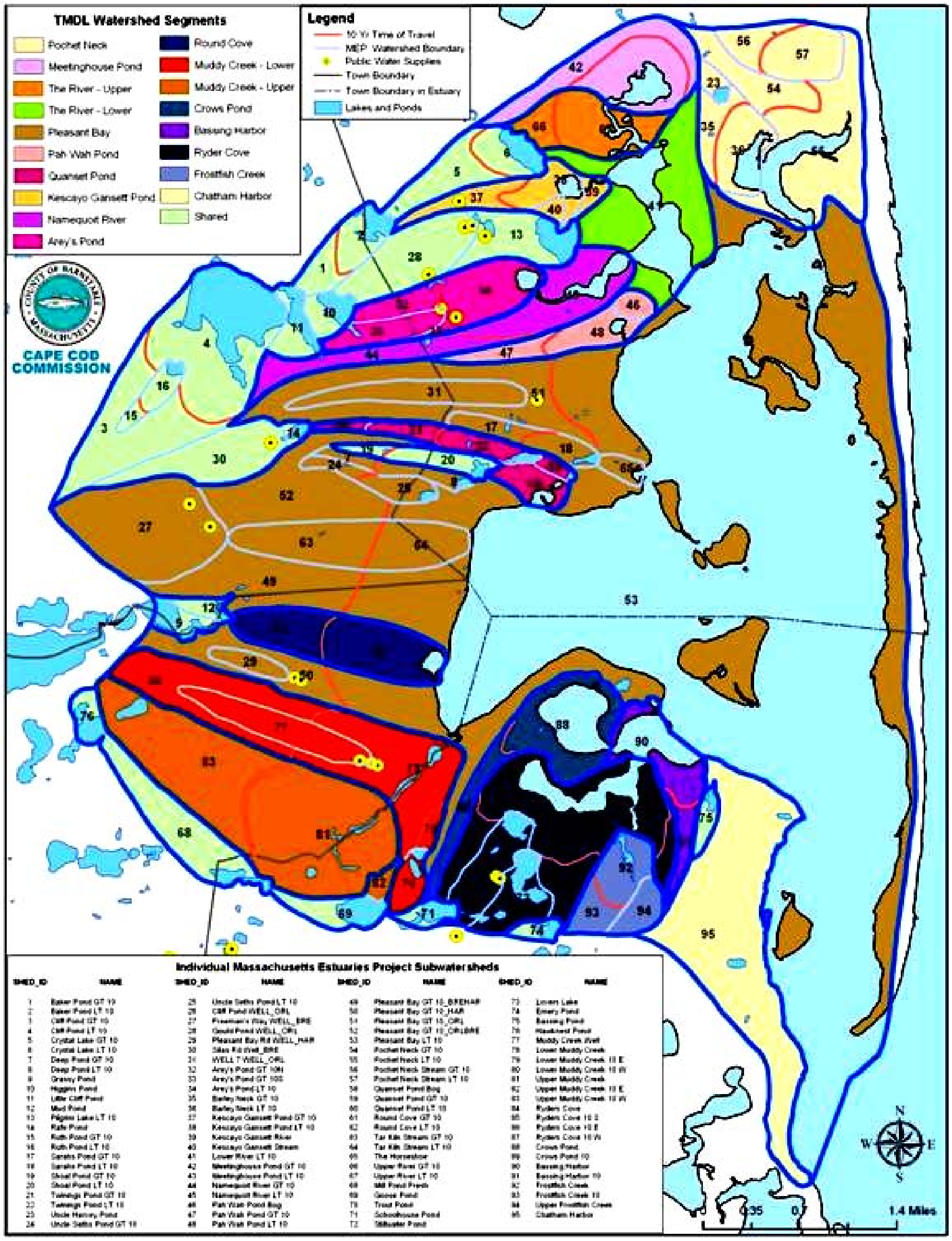


Figure 4.3 The Watershed and Sub-Watersheds of Pleasant Bay

Figure 4.4 Contributing Sub-Embayments of Pleasant Bay

4.2.2 Geology and Hydrogeology

The hydrogeology of this watershed, like most on Cape Cod, consists predominantly of glacial deposits of sand and gravel. Several glacial kettle-hole ponds characterize the Pleasant Bay Watershed, the largest being Cliff Pond, Little Cliff Pond, Higgins Pond, Pilgrim Pond and Crystal Lake (Figure 4.2). The Pleasant Bay Watershed is within the Monomoy Lens waters resources area - a groundwater lens that provides both drinking water and surface water habitat. This groundwater system is also the recipient of the nitrogen load impacts that are derived from wastewater discharges and fertilizer use throughout this area. For more on the Monomoy Lens see http://simlab.uri.edu/cara/monomoy.htm and http://pubs.usgs.gov/sim/2004/2857/pdf/sim_plate.pdf.

Unlike off Cape locations where surface topographic features characterize a watershed's boundary and drainage pattern, this Cape Cod groundwatershed is defined by the elevation and direction of flow of its water table (Cambareri and Eichner 1998, Millham and Howes 1994 a, b). Pleasant Bays sub-embayments are of varying size and hydraulic complexity; each defined by their rates of flushing, salinity, shallow depths and proximity to a heavily developed and populated sub-watershed.

4.2.3 Water Quality

Pleasant Bay and its tributaries have been designated by the MassDEP in its Cape Cod Watershed Water Quality Assessment Report (http://www.mass.gov/dep/water/resources/96wqar.pdf) as possessing outstanding resource waters (ORW) and classified as Class SA waters (Appendix C). Class SA waters are defined "as an excellent habitat for fish, other aquatic life and wildlife and for primary and secondary recreation. In approved areas they shall be suitable for shellfish harvesting without depuration (Open Shellfishing Areas)".

Through the efforts of the Chatham and Pleasant Bay Alliance Water Quality Monitoring Programs, both with MassDEP approved Quality Assurance Project Plans (QAPP), the water quality status of Pleasant Bay is well defined and served the needs of the MEP to characterize the levels of water quality impairment, lost habitat, and reductions in watershed nitrogen load needed to restore water quality (see: see: http://www.mass.gov/czm/docs/word/general_qapp.doc). While water quality for Pleasant Bay as a whole has been excellent, consistent with its SA designation, there has been a decline most notably in the upper reaches of those sub-embayments that have been affected by the population pressures of development and by limited tidal flow and flushing. By example, water quality monitoring in the upper reaches of the sub-embayments to Little Pleasant Bay has identified moderately high nitrogen levels that are consistent with eelgrass loss. Over the years, these water quality monitoring efforts as well as others have documented water quality impairment and habitat loss. These include the following:

- 1998. The Cape Cod Coastal Embayment Project study (http://www.capecodcommission.org/water/exec-sum.htm) by the Cape Cod Commission, funded with EPA section 319 MassDEP pass through money, was among the first to document water quality degradation to Pleasant Bay with sub-watershed nitrogen loads.
- 2002. MassDEP funded studies by the Cape Cod Commission in the mid to late 1990s under section 604b of the Clean Water Act, (99-03/604 Cape Cod Coastal Nitrogen Loading Studies). This study used the results from early 604b funded water quality and revised tidal flushing studies in the Pleasant Bay system, including the Mashpee River, to produce nitrogen management options for this system.
- 2003. Howes B., S. W. Kelley, J. S. Ramsey, R. Samimy, D. Schlezinger, E. Eichner. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Stage Harbor, Sulpher Springs, Taylors Pond, Bassing Harbor and Mudy Creek, Chatham,

Massachusetts. MEP, MassDEP. Boston, MA (http://www.oceanscience.net/estuaries/report/Chatham/Chatham_Re-eval_Report.pdf).

- 2006. Howes B., S. W. Kelley, J. S. Ramsey, R. Samimy, D. Schlezinger, E. Eichner. Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Pleasant Bay, Chatham, Massachusetts. MEP, MassDEP. Boston, MA (http://www.oceanscience.net/estuaries/Pleasant_Bay.htm).

In view of this embayment's designation as an ACEC, this coastal watershed and its embayment system constitutes an important component of this region's natural and cultural resources. Despite the biological diversity and the fact that most of the open waters of Pleasant Bay meet and exceed the Commonwealth's surface water quality standards, it is important to understand that many of these sub-embayments are in close proximity to areas of population density and limited tidal flushing, which collectively brings two opposing elements to bear: 1) as a protected marine shoreline this resource is popular for boating, recreation, and land development and 2) as an enclosed embayment with limited tidal flushing, the pollutants these bodies receive from these densely developed sub-watersheds from groundwater and stormwater runoff results in an accumulation of nitrogen that is not readily flushed. As a result, these sub-embayments are at risk from further eutrophication from the high nutrient loads they receive.

Past and recent water quality studies have confirmed water quality degradation. These include the 2004 Integrated List of Waters (http://www.mass.gov/dep/water/resources/2004cmt3.pdf) and its updated MA Year 2006 Integrated List of Waters (http://www.mass.gov/dep/water/resources/2006il4.pdf) that identify the impairment of four of Pleasant Bay's sub-embayments and require TMDLs (Category 5) to comply with the Federal Clean Water Act under Section 303(d) (Table 4.2). The environmental damage affecting these sub-embayments include pollutant loadings from nutrients and pathogens, periodic decreases in dissolved oxygen, decreased diversity of benthic animals, and periodic algal blooms (Table 4.3).

Table 4.2 Pleasant Bay Waters in Category 5 of the Massachusetts 2002 and 2004 Integrated List

Name	Waterbody Segment	Description	Size	Pollutant Listed
Crows Pond	MA96-47_2002	To Bassing Harbor, Chatham	0.19 sq mi	-Nutrients
Frost Fish Creek	MA96-49_2002	Outlet from cranberry bog northwest of Stony Hill Road to confluence with Ryder Cove, Chatham	0.02 sq mi	-Nutrients -Pathogens
Ryder Cove	MA96-50_2002	Chatham	0.17 sq mi	-Nutrients -Pathogens
Muddy Creek	MA96-51_2002	Outlet of small unnamed pond south of Countyside Drive and north-northeast of Old Queen Anne Road to mouth at Pleasant Bay, Chatham	0.05 sq mi	-Pathogens

As noted in Table 4.3, the TMDL report identifies several other water body segments that have the potential of being listed in Category Five when sufficient data has been compiled for these segments. Other sub-embayments in the TMDL report were determined to be high priorities based on three factors: (1) extent of impairment in the sub-embayments; (2) the initiative the towns took to assess the entire system; and (3) the commitment by the towns to restore and improve the sub-embayments. In particular, these sub-embayments are at risk of further degradation due to N loading from increasingly developed watersheds. (See http://www.mass.gov/dep/water/resources/pbtmdl.pdf).

Table 4.3 Comparison of parameters for the impairment of waterbodies within the Pleasant Bay System

Pleasant Bay System	MassDEP Listed Impaired Parameter	SMAST Listed Impaired Parameter	Pleasant Bay System	MassDEP Listed Impaired Parameter	SMAST Listed Impaired Parameter
Meetinghouse Pond & Outlet		-Nutrients -DO level -Chlorophyll -Macroalgae -Benthic fauna	Muddy Creek - Upper	-Pathogens	-Nutrients -DO level -Chlorophyll -Benthic fauna
Lonnies Pond		-Nutrients -DO level -Chlorophyll -Macroalgae -Benthic fauna	Muddy Creek - Lower	-Pathogens	-Nutrients -DO level -Chlorophyll -Eelgrass loss -Benthic fauna
Areys Pond & Outlet		-Nutrients -DO level -Chlorophyll -Macroalgae -Benthic fauna	Crows Pond[1]	-Nutrients	-Chlorophyll -Macroalgae -Eelgrass loss -Benthic fauna
The River		-Nutrients -DO level -Chlorophyll -Macroalgae -Eelgrass loss\ - Benthic fauna	Bassing Harbor (Lower Basin)[1]		-Chlorophyll -Eelgrass loss -Benthic fauna
Paw Wah Pond		-Nutrients -DO level -Chlorophyll -Macroalgae -Benthic fauna	Frost Fish Creek	-Nutrients -Pathogens	-Nutrients -Chlorophyll -Macroalgae -Benthic fauna
Quanset Pond		-Nutrients -DO level -Chlorophyll -Benthic fauna	Pochet		-Nutrients -DO level -Benthic fauna
Round Cove		-Nutrients -DO level -Chlorophyll -Benthic fauna	Little Pleasant Bay		-Nutrients -DO level -Eelgrass loss -Benthic fauna
Ryders Cove	-Nutrients -Pathogens	-Nutrients -Chlorophyll -Macroalgae -Eelgrass loss -Benthic fauna	Pleasant Bay		-Nutrients -DO level -Chlorophyll -Eelgrass loss -Benthic fauna

[1] These segments are also classified as Category 5 on the Draft 2006 Integrated List.

The Pleasant Bay System is comprised of a variety of watersheds displaying a range of habitat health from "Healthy" (supportive of eelgrass, infaunal communities and with little oxygen stress) to "Degraded" (absence of eelgrass and benthic animals and periodic hypoxia/anoxia). There appears to be a clear relationship between habitat health and the level of nitrogen enrichment; habitat health is highest near the tidal inlet with the Atlantic Ocean and poorest in the less flushed enclosed embayments and the upper reaches of the embayments furthest away from the inlet.

4.2.4 Eelgrass Habitat

The first aerial photographic surveys of Pleasant Bay in 1951 documented eelgrass beds with significant coverage within the Pleasant Bay Embayment (Table 4.4, Figure 4.5). Personal communication with Charles Costello, MassDEP Eelgrass Mapping Program, suggests that these waters were of the highest quality without the impacts associated with nitrogen loading. However, follow-up MassDEP field surveys in 1995 and in 2001 identified an embayment system in decline with significant losses of eelgrass throughout the Pleasant Bay System (Tables 4.3, 4.4), ranging from 51% in Pleasant Bay North, 59% in Pleasant Bay South, and 58% overall.

Table 4.4 Pleasant Bay's Eelgrass Acreage (Past and Present)

Embayment	**1951 (Acres)**	**1995 (Acres)**	**2006 Acres)**	**Percent Loss since 1951**
Pleasant Bay North	358.62	299.89	182.03	51%
Pleasant Bay South	2030.71	1447.84	1199.26	59%
Overall	2389.33	1747.73	1381.29	58%

The nitrogen loads affecting this embayment system have been sufficient to promote microalgal blooms during the summer months, as suggested in Table 4.3 by the high chlorophyll a levels (exceeding 20 μ/L). As stated earlier, these algal blooms can be of sufficient density in the water column to shade the floor of the seabed. Without adequate sunlight, the eelgrass beds are unable to sustain their energy requirements via photosynthesis and eventually perish. For the same reason, these ecosystems cannot be reestablished as habitat and spawning ground, nursery, and protective cover for commercially important finfish, and shellfish without a major reduction in nitrogen loading. The eelgrass beds that were first identified in 1951 have since been replaced by macro algae, which are undesirable because they do not provide the high quality habitat for fish and invertebrates. In the most severe cases, this habitat degradation has the potential of leading to periodic fish kills, unpleasant odors and scums, and near loss of the benthic community and/or presence of only the most stress-tolerant species of benthic animals.

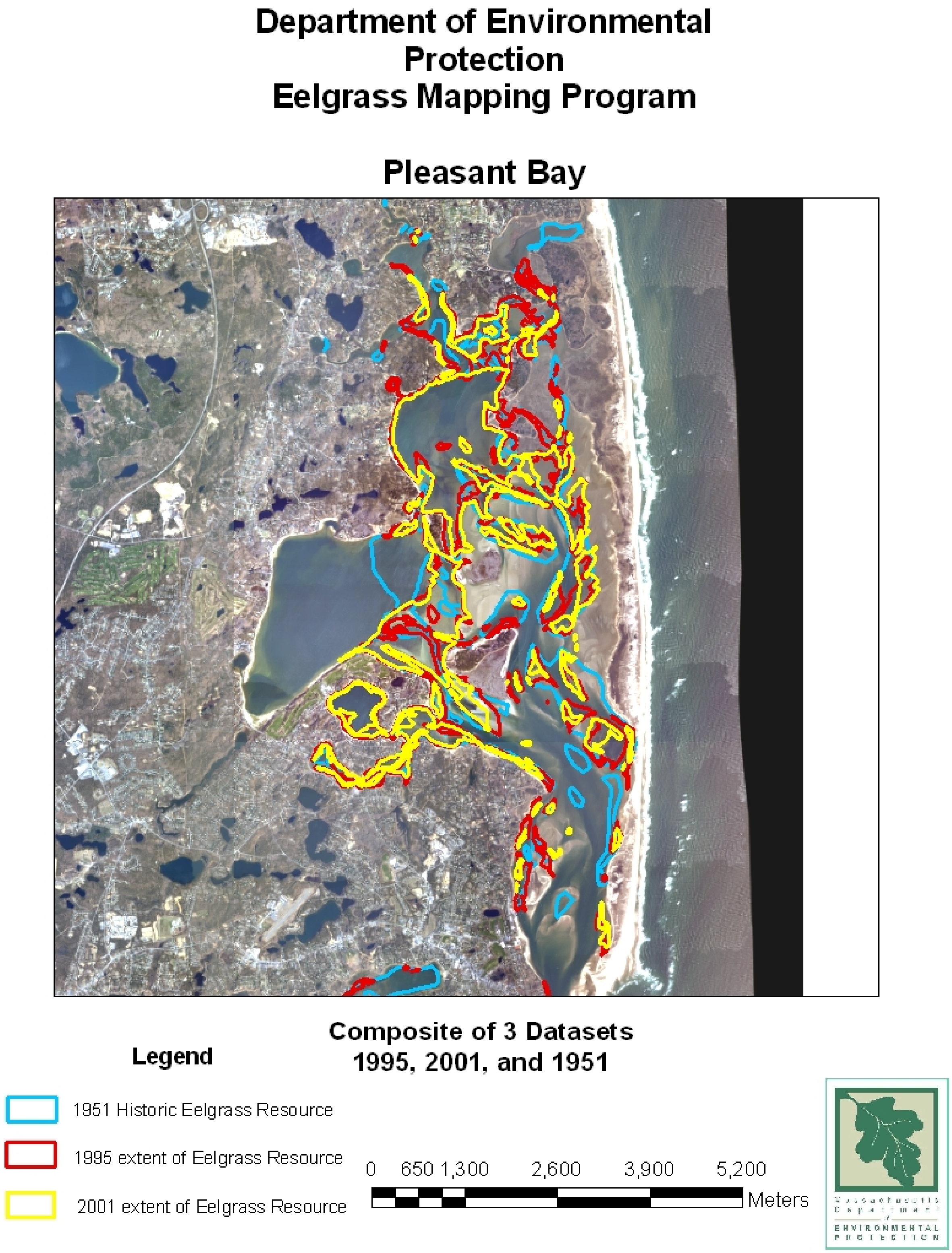


Figure 4.5 Past and present distribution of eelgrass beds in the Pleasant Bay system

4.2.5 Watershed Land Use

Land use in the watershed, as identified in the MEP technical report, is predominantly residential (36%) and public municipal (35%) (Figure 4.6). In the sub-watersheds, residential land uses vary between 23 and 69%.

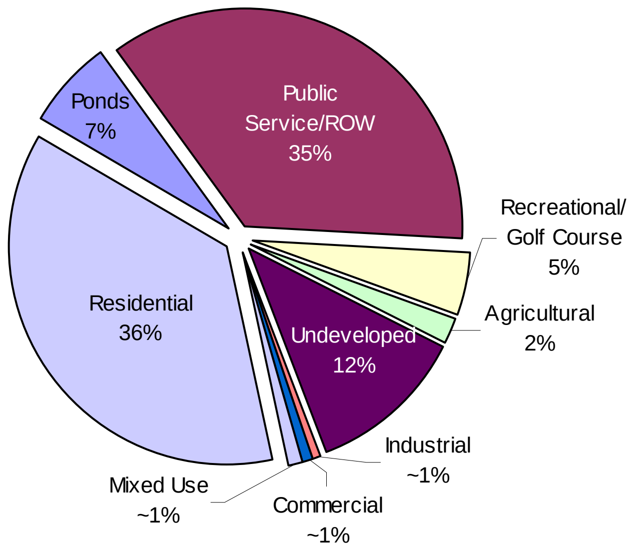


Figure 4.6 Land Use by percent within Pleasant Bay watershed
(Source: Figure IV-2, MEP Tech Report (Howes, B. et. al. 2006))

Public service land uses are the dominant category in sub-watersheds where residential land uses are the second highest percentage and usually represent the second highest percentage in sub-watersheds where residential uses are the highest. Recreational (e.g. golf courses) or undeveloped land uses are usually either the third or the fourth highest percentage land uses. Overall, undeveloped land uses account for 12% of the Pleasant Bay watershed, while commercial properties account for approximately 1-2% of the watershed area.

Vegetative cover consists primarily of a mixture pine, locust, and oak with limited agricultural production, confined to cranberry production.

4.3 Sources of Nitrogen

The nitrogen sources that affect estuarine water quality are many and each has an impact. Table 4.5 and Figure 4.7a-c identify three major sources: atmospheric deposition, sediment regeneration (benthic flux), and those contributed from both natural and anthropogenic sources within the watershed. Figure 4.7(a) identifies all sources of nitrogen loading affecting estuarine water quality; demonstrating that 38% are from septic loads of nitrogen from Title 5 systems. Figure 4.7(b) identifies all sources of nitrogen affecting the watershed; showing that 69% of the watershed loads are from Title 5 systems. While Figure 4.7(c) focuses only on the sources of the nitrogen in the watershed that can be controlled (septic, stormwater, and fertilizers); showing that 75% of this load is from Title 5 septic systems.

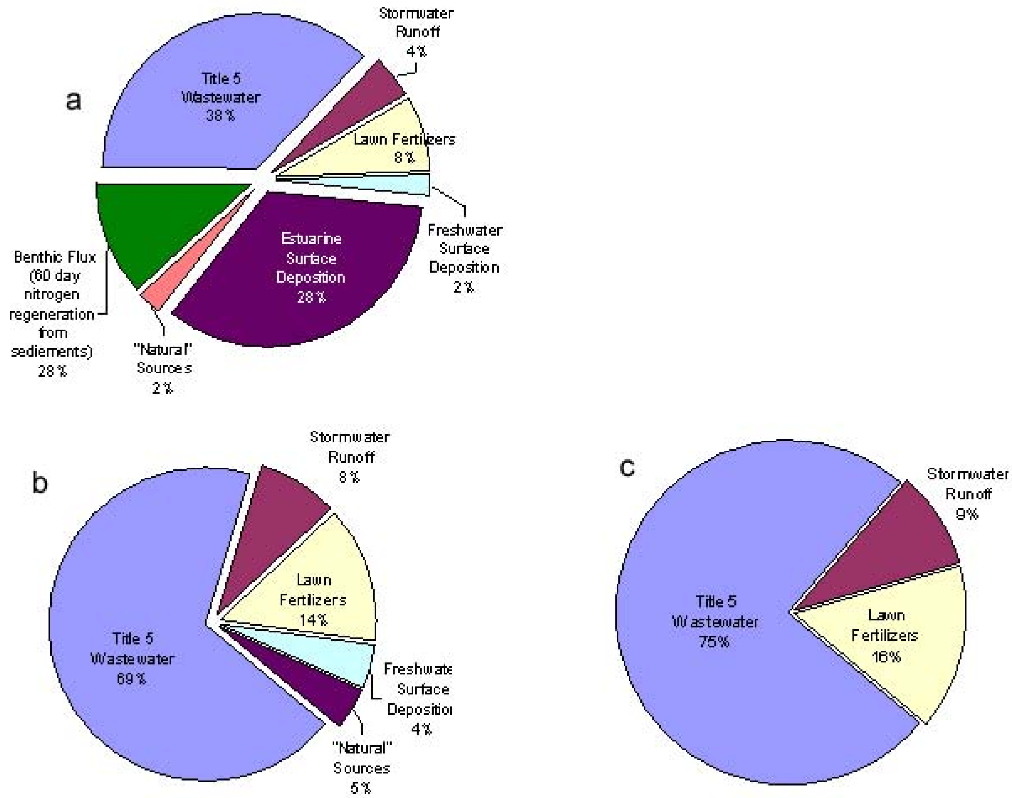


Figure 4.7a-c Pleasant Bay Estuary and Watershed Sources of Nitrogen Loading - (a) Overall unattenuated nitrogen loads, (b) Unattenuated nitrogen loads affecting the Watershed, and (c) Percentage of controllable nitrogen loads (stormwater, fertilizers, and treatment plants) (Source: SMAST Pleasant Bay Technical Report (Howes, B. et. al., 2006), Chapter IV, Table IV-4) and Executive Summary (Appendix 0), Table ES-1b)

Figure 4.7(a) also shows that nearly 28% of the overall load comes from the biological regeneration of nitrogen in the estuarine sediments; the highest rate of regeneration of the 3 piloted embayment systems.

Table 4.5 Sources of Unattenuated Nitrogen Loads to the Pleasant Bay Embayment and Watershed

Source	Kg N/Year	Percent
Title 5 Wastewater	34290	38%
Stormwater Runoff	4074	4%
Lawn Fertilizers	7117	8%
Water Body Surface	33403	2%
"Natural" Sources	2283	2%
Estuarine Atmospheric Deposition	31278	28%
Benthic Flux (nitrogen regeneration from sediments (60 days))	67349	28%
Unattenuated Load	179794	100%

Wastewater flows from conventional Title 5 on-site septic systems represent the most significant percentage (75 percent) of the controllable watershed load, whether they fail or comply with code requirements. The Pleasant Bay Watershed towns have begun the CWMP planning process to address the technical, managerial, financial, and inter-municipal coordination issues prior to the selection of a wastewater treatment option for town and/or watershed-wide utilization and benefit.

It is likely, following the completion and approval of a MassDEP approved CWMP that the towns will consider the implementation a variety of wastewater treatment options, singularly or in combination. It is highly possible that the excess capacity of an existing treatment plant will be insufficient to treat the required additional flows. New plants may be needed, while existing plants may be incorporated within a proposed overall watershed-wide system. In addition, comprehensive wastewater management planning and implementation may require additional nitrogen reduction technologies to lower the nitrate discharges of existing plants below the current 10 mg/l permit limit; thus maximizing on costs and benefits, flows, and nitrate reductions at Title 5 septic system locations.

4.3.1 Wastewater Treatment

Chatham's centralized wastewater treatment facility serves a small portion of the Pleasant Bay watershed in downtown Chatham with the discharge outside this watershed. The remaining portions of Chatham, as well as the towns of Orleans, Brewster, and Harwich are without municipal sewer; primarily dependent on private on-site wastewater disposal systems. In addition, Orleans hosts a regional septage treatment plant and a small number of private sewage treatment plants that serve the needs of locations with wastewater flows exceeding 10,000 gpd.

CWMP planning is underway in all four towns but most advanced in the Towns of Chatham and Orleans. As of September 2008, Chatham completed its CWMP and awaits MassDEP review and approval to begin construction of the sewer extensions that will ultimately sewer all locations of the community. Chatham will continue to use its existing treatment plant, which discharges its wastewater outside the Pleasant Bay Watershed. In November 2008, Orleans voters approved the town's Draft CWMP and will soon be submitting a plan to the state for MEPA approval and ultimately to MassDEP for its review and approval. Harwich is developing its draft CWMP while the town of Brewster has just begun.

4.3.2 Fertilizer Use

Fertilizer applications to lawns and golf course greens are the second largest source of controllable watershed nitrogen loading, with lawns being the more predominant source. Fertilizers account for 8 percent of the overall Pleasant Bay watershed nitrogen load (Figure 4.7a), 14 percent of the watershed load (Figure 4.7b) and 16 percent of the controllable watershed nitrogen load (Figure 4.7c).

In view of the fact that fertilizer use is the second largest controllable source of nitrogen, the Pleasant Bay Alliance took the initiative to apply for a Cape Cod Wastewater Protection Collaborative grant to: (1) determine the appropriate N leaching rate for fertilizer use in the watershed; (2) assess the implications, if any, of the leaching rate on established MEP watershed loads; (3) develop and implement appropriate management responses, including public education. The study will ultimately provide useful information concerning application rates that are protective of Pleasant Bay and other nitrogen sensitive embayments. Pleasant Bay has four golf courses (Captains Golf Course, Eastward Ho in Chatham, Chatham Seaside Links, and Cape Cod National Golf Club on the border between Brewster and Harwich.) and 36 percent of the watershed that is in residential development with many lawns that undergo regular fertilizer applications. The Popponesset Pilot has found that golf courses contribute 24% of the unattenuated fertilizer load, equal to 2.4% of the total unattenuated controllable load. Also important to understand is that nitrogen leaching from fertilizer applications on golf courses can be a larger share of the load in the sub-watersheds where they are located since the golf course is often in such close proximity to the bay where natural attenuation may not reduce those loads prior to entering the coastal embayment.

Figure 4.8. View of Pleasant Bay from the Eastward Ho Golf Course in Chatham

4.3.3 Stormwater

Stormwater runoff impacts to the embayment system as a whole is minimal at 4% and this represents only 9% of the controllable load from the watershed (Figure 4.7a. and c).

4.4 Demographics

4.4.1 Land Use Change

During the past 58 years, land use development pressures within the Pleasant Watershed have been dramatic with a 38 percent loss of undeveloped land (Table 4.6; Figures 4.9). Coincident with this loss was a 267 percent increase in developed acreage, consisting primarily from the construction of year round single-family homes and the conversion of seasonal to year-round residences. These changes are also reflected in the loss of forest land.

Water quality problems have been inevitable with this transformation of undeveloped open space to the construction of residential subdivisions primarily from on-site septic systems, and to a lesser extent from stormwater runoff, and the use of lawn fertilizers (Figure 4.7). The installation of onsite Title 5 systems which represent the dominant waterwater disposal option in the unsewered areas of the watershed has greatly affected the water quality of the sub-embayments. These discharges enter the groundwater

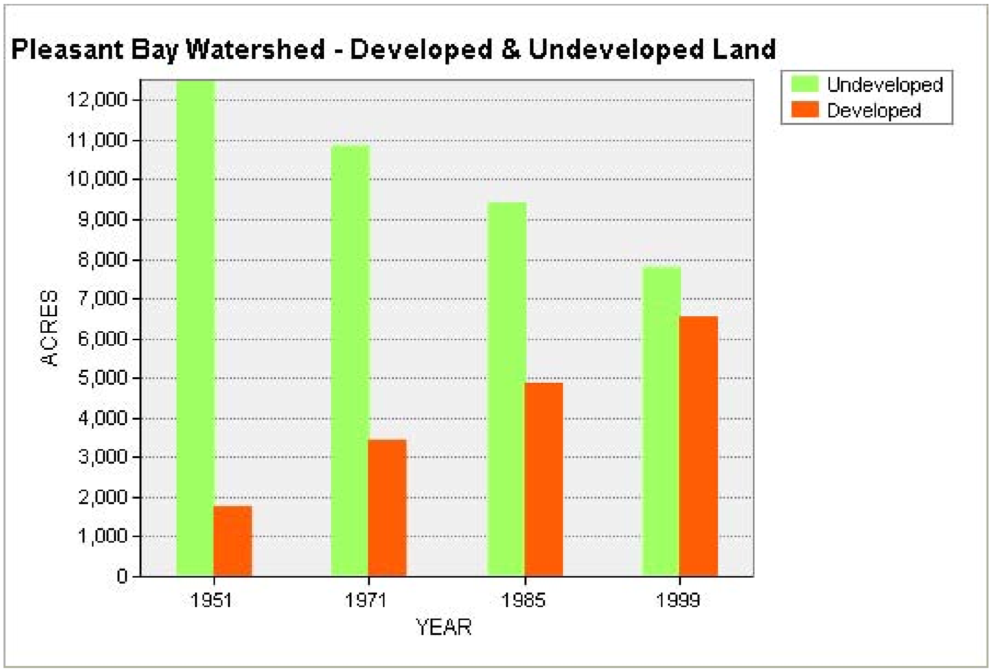


Figure 4.9 Chart showing change in developed and undeveloped land between 1951 and 1999 in the Pleasant Bay Watershed (source: MassDEP GIS)

and eventually affect down gradient surface water bodies as this groundwater flows seaward. In the sandy soils of Cape Cod, the movement of nitrogen in groundwater is unimpeded, flowing at the same rate as groundwater at an average rate of one foot per day.

Table 4.6 Developed and undeveloped land (1951, 1971, 1985, 1999) in the Pleasant Bay Watershed (MassGIS)

YEAR	Developed Acreage	Undeveloped Acreage	Total Acreage *	Percent Developed +	Percent Undeveloped +	TOTAL PCT
1951	1775	12529	14304	12%	88%	100%
1971	3437	10865	14302	24%	76%	100%
1985	4859	9443	14302	34%	66%	100%
1999	6521	7808	14329	46%	54%	100%

* Exclusive of lakes and ponds
+ Refer to Figure 4.10 for landuse codes for these two categories of land use.

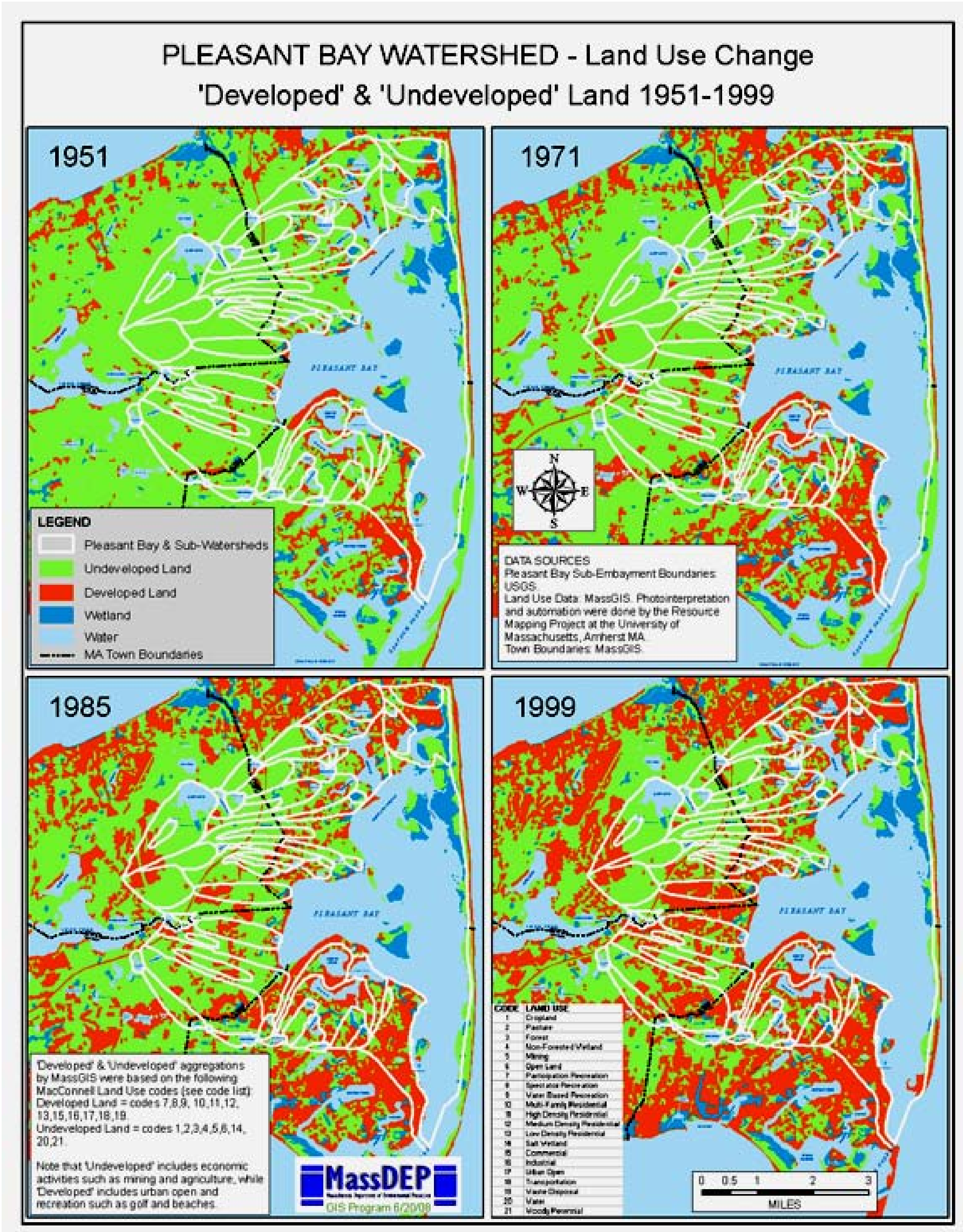


Figure 4.10 Map showing landuse change (1951, 1971, 1985, 1999) in the Pleasant Bay Watershed represented as developed and undeveloped (source: MassDEP GIS)

4.4.2 Population Growth

US Census data indicate a population growth rate that has consumed an increasingly greater percentage of the open space in the three towns since the 1950s (Figures 4.9. and 4.10; Tables 4.6-4.7), with the Town of Brewster and Harwich taking the lead for all time intervals (1950 to 2000). The Town of Brewster led all towns with a 923 percent increase in its population since 1950 (16 percent of the Pleasant Bay Watershed); followed by the Town of Harwich (13 percent of Pleasant Bay Watershed) with a 367 percent increase, and the Town of Orleans (41 percent of the Pleasant Bay Watershed) with a 261 percent increase. While these rates reflect town wide patterns, they also reflect increases in residential development and wastewater discharges within the watershed from on-site water septic systems, mostly in the towns of Orleans representing 41 percent, followed by Chatham with 30 percent of the land area within the Pleasant Bay watershed. The high percentage population and land development in the Town of Brewster at its headwaters is not expected to have affected Pleasant Bay because much of its nitrogen load undergoes natural attenuation as this load passes thorough a number of wetland systems and also because a high percentage of this watershed is protected open space either for passive recreation or wellhead protection.

Table 4.7 Percent Population Growth, since 1950, for the Pleasant Bay Watershed Towns

Town	1950 – 1960	1950-1970	1950-1980	1950-1990	1950-2000
Chatham	33.2	85.4	147.1	167.8	169.6
Orleans	33.1	73.7	201.6	231.9	260.5
Brewster	25.2	81.4	429.5	755.1	922.7
Harwich	41.5	122.4	238.7	287.9	367.6
Overall	34.97	94.7	225.7	296.5	351.4

The significance of these statistics is clear; Title 5 on-site septic systems continue to serve new households with ever increasing nitrogen loads to this estuary. The 2006 MEP Technical Report

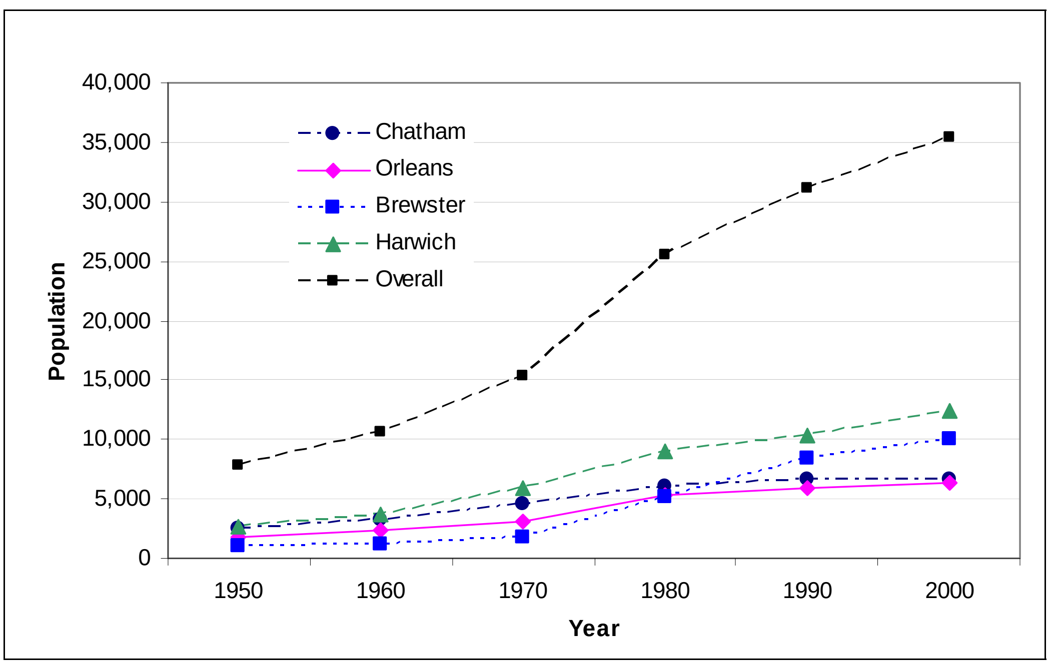


Figure 4.11 Percent Population Increase since 1950 for Pleasant Bay Watershed

Towns of Chatham, Orleans, Brewster, and Harwich

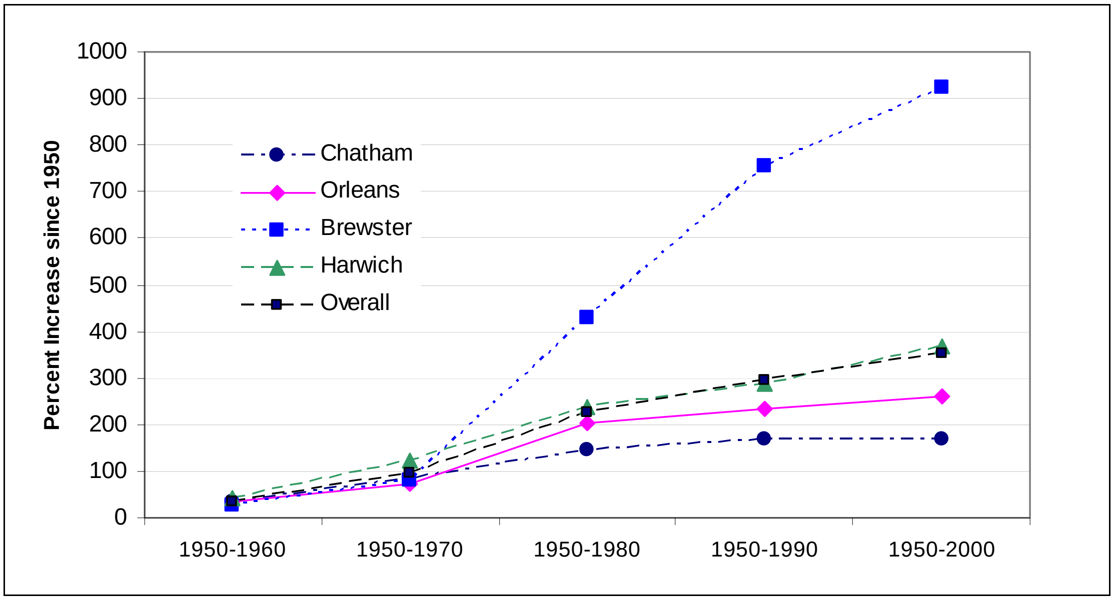


Figure 4.12 Population Growth since 1950 for the Pleasant Bay Watershed Towns

recognizes these increases are inevitable and provides an estimate of these future loads under the build-out conditions under current zoning for each of the towns sharing this watershed.

4.4.3 Population Density

US Census population density statistics, reported as persons per square mile, are also helpful in assessing land use development because it defines locations within the subwatershed where the wastewater burden affecting the Pleasant Bay embayments are the greatest (Figure 4.13).

It is well understood that as population density increases, and the accompanying wastewater disposal systems are installed, the nitrogen loads to the estuary significantly increases. This correlation between population density and increases in nitrogen loads is well established (Giblin and Gaines (1990). Their investigation of nitrogen loading to a small marine cove in Orleans, MA identified that septic-derived loads of nitrogen were greatest in those areas where building density was the greatest. Also, the nitrate in groundwater behaved conservatively in the sandy soils where the groundwater flow rates were the highest; indicating that natural attenuation, via denitrification, did not reduce these loads prior to reaching the estuary.

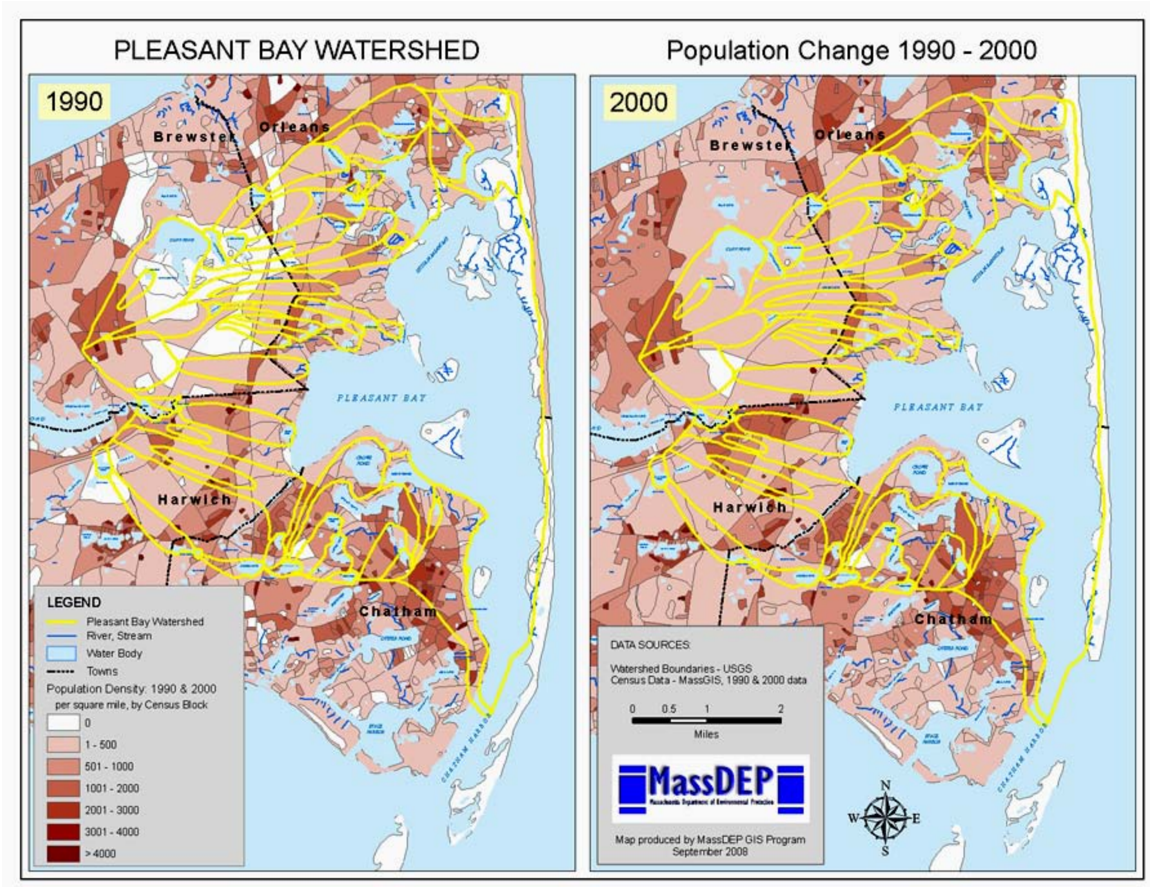


Figure 4.13 Changes in Population Density within the Pleasant Bay Watershed from 1990 to 2000

4.5 The Pleasant Bay Alliance Team

This Pilot Project enlisted the participation of the Pleasant Bay Resource Management Alliance (PBA or Alliance), an inter-municipal organization that was formed in 1998 through an MOA with the towns of Chatham, Orleans and Harwich. The Alliance is responsible with implementing the recommendations of the town and state approved ACEC Resource Management Plan as updated. The Alliance has established work groups to implement areas of the resource management plan, including the recently formed watershed planning work group to address nutrient loading issues. As defined in its updated Pleasant Bay Resource Management Plan (2008) (http://www.pleasantbay.org/PleasantBayResMgt%20Plan08.pdf), the goals of the watershed planning work group are to:

- Continue to facilitate watershed-based collaboration to address nitrogen loading
- Support and encourage the four watershed towns to make progress in developing CWMPs
- Implement comprehensive wastewater management plans (CWMPs) that encompass the Pleasant Bay watershed, and
- Promote watershed-based collaboration to achieve total nitrogen Total Maximum Daily Loads (TMDLs) through the efforts of the Alliance's watershed work group to:

- Coordinate wastewater planning by undertaking plans and studies that will benefit multiple towns and coordinating relevant sections of towns' CWMPs, and
- Sponsor technical studies and model runs that explore system-wide issues and conditions and help to identify cost effective solutions to achieve targeted thresholds.

Because the Alliance had been involved in inter-municipal watershed based planning for over 4 years, it was clear the Pilot should enlist the participation of the Alliance. In addition, MassDEP representation had been ongoing, on an advisory basis for the last four years. Secondly, MassDEP and the Alliance had an invaluable recorded history of those many meetings that addressed how the towns would address inter-municipal, watershed-based planning and implementation; especially how the nitrogen reductions defined in the MEP Technical and the EPA approved TMDL Reports would be apportioned and implemented by the four towns.

Table 4.8 Pleasant Bay Watershed Pilot Team

Name	Affiliation
Chuck Bartlett	Town of Chatham, Representative, PBA Steering Committee
Judith Bruce	Town of Orleans, Representative, PBA Steering Committee
Jillian Douglass	Town of Brewster, Asst Town Admin, PBA Steering Committee
Larry Ballantine	Town of Harwich Representative, PBA Steering Committee
Chris Miller	Town of Brewster, Director of Natural Resources, PBA Steering Committee
Frank Sampson	Town of Harwich, Chair, Water Quality Task Force, PBA TRC
Robert Canning	Town of Orleans, Health Dept., PBA TRC
George Meservey	Town of Orleans, Director, Community Development, PBA TRC
Bob Duncanson	Town of Chatham, Director, Health & Resources Dept., PBA TRC
Carole Ridley	PBA Coordinator
Gussie McKucisk	Town of Orleans, Chair, Cape Cod Water Protection Collaborative
Mike Giggey	Wright- Pierce, Orleans Consultant
Dave Young	Camp Dresser & McKee, Harwich Consultant
Nate Weeks	Stearns and Wheler, Chatham Consultant
Eduard Eichner (former)	Cape Cod Commission, Water Scientist
George Zoto	MassDEP, Project Manager, Hyannis
Brian Dudley	MassDEP, MEP Coordinator, Hyannis

Participation in the work group involves Steering Committee members who are appointed by their selectmen to serve on the Steering Committee, which governs the Alliance as the policy setting body that is also responsible and accountable for coordinating inter-municipal implementation activities. The work group also includes Technical Resource Committee members consisting of the towns' resource management professionals, and the coordinator who is responsible for managing Alliance programs and activities. This workgroup also consists of consultant engineers and agency liaisons from the Cape Cod Commission and MassDEP (Table 4.8). Staff from SMAST participated on an as needed basis to discuss development of and outcome of the selected scenario runs.

Town staff from other offices, typically attended meetings that addressed technical and policy related issues in their area of expertise and responsibility.

4.5.1 Alliance Team Meetings

There was no need to brief Pleasant Bay Alliance members about the MEP process as they were the first regional coalition of communities whose charge was to protect a coastal embayment system. The groundwork for initiating and engaging inter-municipal collaboration within the Pleasant Bay Watershed led to the publication of the first Resource Management Plan in 1998, and updated in 2003, and most recently in 2008 on a five-year schedule.

Unlike the Popponesset and the Three Bays Pilot Projects, there was clearly no one town that took the lead. In this case, it was the Pleasant Bay Alliance, the inter-municipal entity whose charge was defined in 1998 when the Pleasant Bay ACEC was first established.

Since May 2005, PBA meetings discussed several of the topics and issues pertaining to the goals of this Pilot Project, specifically:

- Water Quality Model runs by SMAST proposed by the team to determine how the nitrogen loads to the hydrologically active Pleasant Bay embayment system was affected from the changes in tidal flushing rates resulting from the opening/closing of inlets channel(s) to the to the Bay.
- Inter-municipal Coordination
- Allocating nitrogen load reduction responsibilities among the watershed towns
- Discussion of local and state management and regulatory issues.

Their initial focus was on the development of a white paper that was intended to provide a basis for on-going policy development on implementation issues, as well as for a dialogue with Boards of Selectmen and other key groups. After several months of discussions, the work group decided in November 2005 to suspend discussion of the white paper pending the release of the MEP Technical report and TMDL report. The rationale was that they first needed to know what the TMDL(s) would be, prior to any constructive discussion concerning mitigation. At that time, the work group discussion focused on the review and comment on the draft MEP Technical Report and later the TMDL report, and various public presentations concerning these documents.

However, in late 2006, discussions resumed on TMDL implementation issues when the PBA heard what was learned from the Popponesset Pilot Project (Chapter 2 of this report) and the *Fair Share* approach by the Cape Cod Commission.

4.5.1.1 Coordination and Development of CWMPs

At the Alliance's November 9, 2005 meeting, it was agreed that a watershed-wide CWMP for Pleasant Bay is preferable to the coordination of plans from the individual towns. However, it was not clear how development of a watershed CWMP could be funded or managed. Coordination of individual town CWMPs may be more practical, but may not lead to the same optimization of strategies, either ecologically or economically. Once the MEP technical report was distributed in 2006, it was easier to answer questions about whether and how to combine or coordinate the CWMP process. (Also see chapter 7 for guidance on the inter-municipal CWMP process.)

4.5.1.2 Permitting

A great deal of discussion centered on watershed permitting at the PBA's May 2005 meeting concerning the following issues:

- How would a watershed permit be issued?
- To what entity would a watershed permit be issued?
- What would a watershed permit contain?
- How would a watershed permit be enforced?

It was agreed that it was unlikely that MassDEP would treat individual septic systems as point sources. Therefore, groundwater discharge permits would go to a larger entity (town or district agency) and not an individual septic system owner.

The following permitting scenarios were discussed:

- MassDEP approves a CWMP and issues a permit to the town/district to implement the CWMP, and the district interfaces with the towns to confirm that implementation is in progress according to plan.
- Towns/district may also be issued permits for groundwater discharges (e.g. treatment plants or small neighborhood treatment systems).
- Individual systems would be permitted at the local/district level depending on how the affected town and MassDEP agreed to structure permitting.

This could mean different permitting levels. Some issued by MassDEP to the towns or district for the implementation of the MassDEP approved CWMP, and others issued by the towns/district to homeowners/developers for individual systems.

Unresolved Questions for the Alliance:

- How would the flow of permits occur so that there is the ability to achieve the TMDLs and monitor and enforce compliance?
- Who/what entity would be responsible for compliance reporting?

Although no follow-up action was taken, it was agreed that a watershed permit, if issued, should be:

- Designed to require timely progress toward an agreed upon goal
- Issued to an entity capable of implementation
- Include penalties for non-compliance
- Renewed with enough frequency to allow for adaptive management (7-20-05)

Subsequently, the Alliance communicated additional questions about monitoring and compliance issues to MassDEP on behalf of the towns. These and other issues, as lessons learned, are presented in Section 4.10 (p. 151) and Chapter 6 of this report for use by MassDEP in its efforts to assist town's in overcoming the barriers for watershed-wide TMDL planning and implementation.

4.6 Water Quality Modeling Parameters

This section briefly defines some modeling parameters that distinguish Pleasant Bay from the Popponesset and the Three Bays embayments. They include the: (1) consideration of biologically active nitrogen or bioactive nitrogen; and (2) use of three sentinel stations; and (3) connection between water quality and a dynamic barrier beach system that historically changes in the number and location of its inlets.

4.6.1 Biologically Active Nitrogen

Based on data provided by the town of Chatham and the Pleasant Bay Alliance Water Quality Monitoring Program, the MEP identified high levels of total nitrogen (greater than 0.5 mg/L) with the dissolved organic nitrogen fraction representing a very high percentage of this concentration within Bassing Harbor's waters. However, while this dissolved organic nitrogen is actively cycling, the vast majority is refractory (non-biologically active) within the timeframe of flushing Pleasant Bay S. Since this large pool of nitrogen is non-supportive of phytoplankton production from the biologically active fraction (*i.e.* ammonium and nitrate + nitrite, particulate organic nitrogen), it was necessary to subtract the dissolved organic nitrogen concentration (DON) from total nitrogen (TN) for the purpose of defining that fraction that was biologically active. That value is the bioactive or biologically active nitrogen (also referred as reactive nitrogen in the scientific literature) - the active fraction that is readily available for uptake by phytoplankton and algae production and for use in modeling load reduction to achieve the threshold concentrations for restoration.

Given the biogeochemistry of this estuarine system, defining the nitrogen threshold concentration as bioactive nitrogen has less uncertainty in interpreting when the threshold concentration has been met for the achievement of water quality/habitat restoration. Therefore, while both values of total and bioactive nitrogen form the basis for guiding nitrogen reductions to achieve ecological restoration, the total nitrogen value should only be evaluated in light of the bioactive nitrogen threshold.

Given the large dissolved organic nitrogen pool within Pleasant Bay, the MEP adopted the same approach that was used for the MEP analysis of Bassing Harbor - based on the bioactive nitrogen pool (Howes, B. et al., 2003). The concentrations of bioactive nitrogen appeared to be relatively consistent between embayments both within and outside of Pleasant Bay. The bioactive threshold value was converted to the total nitrogen by adding the dissolved organic nitrogen concentration which was derived for the site from direct measurements.

The nitrogen threshold concentration levels were developed to support both healthy eelgrass and healthy infaunal habitat at the designated sentinel locations. While there is significant variation in the dissolved organic nitrogen levels, the level of bioactive nitrogen supportive of healthy eelgrass habitat appeared relatively constant. Therefore, the MEP set a single eelgrass threshold based upon tidally averaged bioactive N levels and the stability of eelgrass as depicted in coverage from 1951-2001. The eelgrass threshold for bioactive nitrogen was set at 0.16 mg N L^{-1} (nitrogen/liter) based upon the Chatham analysis for Bassing Harbor (Howes, B. et. al.; 2003). That report identified healthy eelgrass communities in both Bassing Harbor, at a bioactive nitrogen concentration of 0.135 mg $N/^{-1}$, and in Stage Harbor at the mouth of Oyster River, at a bioactive nitrogen concentration of 0.160 mg bioactive N L^{-1}. The higher value of 0.16 mg N L^{-1} was used since the eelgrass habitat in Bassing Harbor was below its nitrogen-loading limit at that time. At locations without a documented, historical record for eelgrass, the secondary threshold concentration of 0.21 mg bioactive N L-1 was set for the restoration of benthic animal community (infauna) habitat at the designated small embayment check stations.

4.6.2 Sentinel Stations

The location of the sentinel stations for the Pleasant Bay had to be representative of the large embayment system to assure that water quality meets the desired nitrogen threshold concentration for restoring healthy eelgrass or infaunal (animal) habit throughout the system. While eelgrass is the preferred indicator for habitat restoration and the primary nitrogen management goal whenever historical (1951) record for its presence exists at a designated site, small subembayments exist that have not been documented with historically (1951) supported eelgrass habitats. For these sub-embayments, restoration and maintenance of healthy animal communities is the secondary management goal. The sites selected as primary sentinel stations had stable communities and had not shown the onset of impairment with slightly higher nitrogen concentrations. On the other hand, when this evidence was lacking or conditions were not suitable for eelgrass habitat, secondary stations or “check points” were designed for infaunal (animal) habitat restoration. The ultimate goal is to achieve the nitrogen threshold concentration to restore or maintain SA waters or high habitat quality (defined as supportive of eelgrass and infaunal communities).

Three primary sentinel stations were selected for Pleasant Bay System based on a nitrogen threshold target for the restoration of eelgrass habitat. These include the uppermost reach of Little Pleasant Bay (PBA-12) near Orleans inlet to The River and Pochet, and two within the Bassing Harbor Embayment:

Upper Ryders Cove (PBA-04) and Lower Ryders Cove (CM-13) (see Table VIII-6, MEP Tech Report, Howes, B. et. al, 2006).

Several secondary "check stations" or sentinel subembayments were also designated because some were semi-enclosed with limited tidal flushing. These secondary stations were selected for use in deciding if the nitrogen reductions within the watershed would meet the secondary thresholds necessary for the restoration of infaunal habitat. These secondary stations were located based on their proximity to the inland-most reach - as this is typically where water quality is lowest within an embayment system. The sentinel sub-embayment should be sufficiently large to prevent a steep, horizontal water quality gradient as would be expected in the upper reaches of the estuary where a river or stream discharges its freshwater to a narrow and shallow headwater estuarine site. This second criterion is helpful because it can accurately determine the nitrogen level baseline for use in conducting predictive water quality modeling runs. As a result, when water quality is achieved to meet the restoration goals for habitat at these sub-embayments, habitat restoration will have been achieved throughout the estuary.

After the sentinel stations are selected, the nitrogen level associated with high and stable habitat quality (typically derived from a lower reach of the same or adjacent embayment) is set as the nitrogen threshold concentration or target concentration level. Meeting this threshold is achieved by reducing nitrogen loads to the system. The linked modeling approach can then be used to predict the nitrogen concentrations for different nitrogen reduction scenarios. Once the threshold concentration is met at the sentinel stations, water quality throughout the embayment should be sufficient to support the restoration of appropriate habitat.

4. 6.3 Establishing the Sentinel Threshold Concentration for Habitat Restoration

As part of the MEP, the health of the estuarine habitat was evaluated to establish the water-quality threshold to maintain or improve habitat quality. Nitrogen threshold levels are defined by the MEP as the tidally average water column concentration of nitrogen that will support the habitat quality being sought on the outgoing tide" when the concentrations are the highest. This concentration is ultimately controlled by the watershed load, the inflowing tidal water concentration, the loads from sediment regeneration (benthic flux) and direct atmospheric deposition.

A major finding of the MEP indicates that a single nitrogen threshold for restoring water quality <u>can not</u> be applied equally to all Massachusetts' estuaries. As reported in the Popponesset and Three Bays case studies, 0.38 mg/L total nitrogen served as the nitrogen threshold concentration for these embayment systems and unaffected by dissolved organic carbon, as was the case at several locations in the Pleasant Bay System.

The water quality monitoring data for the Pleasant Bay system indicated a significant variation in total nitrogen that was supportive of healthy eelgrass habitat while the biologically active nitrogen that was supportive was relatively constant ranging from 0.16 to -.21 mg/L bioactive N. As a result of this finding, the MEP Technical Team set the tidally averaged 0.16 mg/L bioactive N level as the nitrogen threshold concentration based upon stable eelgrass beds, as depicted in coverage from 1951-2001 (Figure 4.5).

The eelgrass restoration threshold for Little Pleasant Bay (Station PBA-12) near the inlets to The River and Pochet (as for Ryders Cove) was set at 0.16 mg/L bioactive N. This threshold was derived from the Chatham (Howes, B. et al., 2003) analysis for Bassing Harbor that supported a high quality eelgrass habitat with biologically active nitrogen concentrations in both Bassing Harbor at 0.135 mg/L bioactive N and in Stage Harbor at 0.160 mg/L bioactive N (Oyster River Mouth). The higher 0.16 mg/L bioactive N value from Stage Harbor was set as the threshold concentration to achieve, as the eelgrass habitat in

Bassing Harbor was below its nitrogen loading limit at that time. Even though these and other sentinel locations within the Pleasant Bay system had identified high total nitrogen values (0.57 – 0.77 mg/ TN for Little Pleasant Bay, 0.765 mg/L TN for Pochet (WMO-05), 0.44-0.73 mg/L TN at Ryders Cove (PBA-3)), they all had active eelgrass habitat and a bioactive nitrogen concentration within two tenths (0.14 - 0.28 mg/L bioactive N) of the other. The other feature they had in common was the shallow depth of these waters where the higher total nitrogen values were supported eelgrass habitat because the shading of bottom habitat from algal blooms was less of a factor than in deeper waters. Generally, sentinel stations in shallow water locations were more supportive of eelgrass habitat than those in deep water locations, as there was less of an impact from shading from microalgal blooms; despite the higher nitrogen concentrations. As a result site specific targeted threshold bioactive nitrogen threshold concentrations for the three primary sentinel stations for the Pleasant Bay embayment system varied from 0.16 in Ryders Cove (PBA-03) and Little Pleasant Bay (PBA-12) to 0.21 at Meeting House Pond (WMO-10), Nemequoit River (WMO-06) and others. (see Table 2 of the MassDEP TMDL report for Pleasant Bay).

While eelgrass restoration is the primary nitrogen management goal within the Pleasant Bay System, there are subembayments that do not appear to have a historically (1951) supported eelgrass habitat. For these subembayments, restoration and maintenance of healthy animal communities is the management goal. At present, moderately impaired infaunal communities are present in Ryders Cove (PBA-03) at tidally averaged bioactive nitrogen levels of 0.24 mg/L bioactive N. Similarly, there are moderately impaired infaunal communities, designated primarily by the dominance of amphipods (amphipod mats) in most of the 8 sub-embayments of focus. These communities are present adjacent the inlet to Lonnies Pond (in The River Upper) at bioactive nitrogen levels of 0.22 mg/L bioactive N, in the Namequoit River at 0.22-0.24 mg/L bioactive N and in Round Cove at 0.24 mg/L N. These communities can be found at even higher levels in the fringing shallow areas of deep basins like Areys Pond (0.30 mg/L bioactive N) and Meetinghouse Pond (0.41 mg/L bioactive N). Very shallow waters tend to minimize oxygen depletion that severely stress infaunal communities in deeper basins. Paw Wah Pond is periodically hypoxic and as a result does not presently support infaunal habitat. These data are at higher bioactive nitrogen levels than the healthy infaunal habitat in the lower Pochet Basin (WMO-03) at 0.18 mg/L N. It appears that the infaunal threshold lies between 0.18 and 0.22 mg/L N tidally averaged bioactive nitrogen. Based upon the animal community and nitrogen analysis discussed in Chapter VIII, the restoration goal for the 8 small tributary subbasin systems to Pleasant Bay is to restore a healthy habitat to the full basin in the shallower or more open waters and to the margins in the deep drowned kettles that periodically stratify.

The Pleasant Bay TMDL Report (2007) (http://www.mass.gov/dep/water/resources/pbtmdl.pdf) should be consulted for a more detailed presentation.

4.6.4 Impact of Inlet Formation on Embayment Water Quality

The SMAST Technical Report (Howes, B. et. al, 2006) and the EPA-approved TMDL Report (MassDEP, 2007) have taken into account that water quality within the Pleasant Bay embayment system is highly dependent on the makeup of Nauset Beach barrier beach which encloses much of Pleasant Bay. Any time a breach occurs with the creation of a new inlet or whenever an inlet is closed, water quality within the Pleasant Bay system is directly affected. The addition of an inlet means more tidal exchange and greater flushing while the closure of an inlet has the opposite effect.

The Pilot Project Team was keenly aware of the hydrodynamics of this hydrologically active system based on a long recorded history of Nauset Beach. Within the last twenty years two inlets formed. The first was formed in 1987 along its southern boundary (Figure 4.14 – 4.15) and the second unexpectedly formed in April of 2007 (Figures 4.14). As a result, Pleasant Bay currently exhibits a two-channel system. Ocean water entering through the northerly 2007 breach has its flows directed behind Strong and Sipson's islands into Little Pleasant Bay. The older, southerly 1987 breach has its flows directed around the other side of Strong Island into Big Pleasant Bay and Chatham Harbor.

For a brief summary of the changing makeup of this system, the abstract by Graham Giese (2008) should be read at http://gsa.confex.com/gsa/2008AM/finalprogram/abstract_148715.htm

An aerial video view of the existing two inlet systems can be down loaded at: http://www.revver.com/video/348046/aerial-video-of-new-chatham-break-cape-cod/ and

Photos documenting the changes that have occurred over time can be viewed at: http://www.kerriganairviews.com/CQX2007Storm/

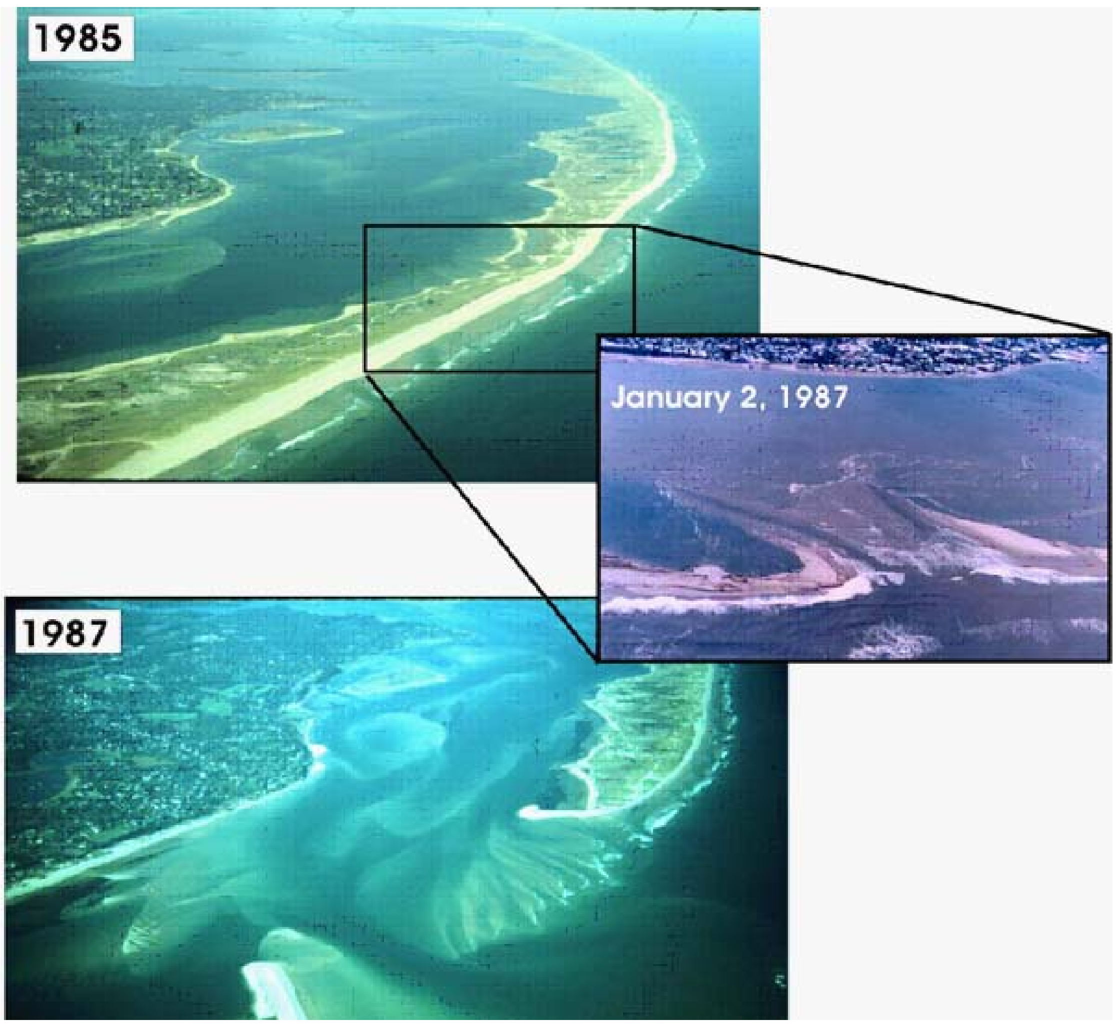


Figure 4.14 Phases of new inlet development pre and post January 2, 1987
Provided by the Town of Chatham, Kelsey-Kennard air view, www.capecodphotos.com

4.7 Pilot Project Scenario Runs

In view of the short-term changes in the configuration of Pleasant Bay, it was understood that before any watershed-based nitrogen reduction scenario runs could proceed that an in depth field survey of current conditions in the Bay was required. It was understood that the underlying hydrologic conditions of Pleasant Bay that provided the scientific basis for the MEP Technical Report and the TMDL were no longer applicable. The updating of the hydrologic conditions of Pleasant Bay began in earnest in November 2007 with funding provided by the US Army Corp of Engineers and the Pleasant Bay Alliance. Key findings of the updated hydrodynamic model ("Hydrodynamic Model of Chatham Harbor/Pleasant Bay including 2007 North Breach") by Ramsey and Kelley (2008) are:

- 40% of the flood tide is coming through the new inlet, with about 4% of that incoming flow actually going out through the old inlet;
- The tidal prism in the system increased 14%;
- The tidal range increased 20% or 0.7 feet at Meeting House Pond, split between high and low tide; perhaps the range is slightly more at fish Pier.
- Going forward, high tides will not get much higher but low tides could get lower.

In view of these and potential future changes, the Alliance chose three model runs that address potential changes in the number and location of future inlets and its affect on Pleasant Bay's water quality. This information will be invaluable in identifying the best options for the CWMPs that are underway with the understanding that this barrier beach may return to a single inlet or, as a worse case, completely enclose the Bay. For the purpose of the Pilot Project, it was decided that the water quality conditions should be predicted for following scenario runs:

- Option 1. Presume the worse-case scenario if the barrier beach re-occupies its pre-1987 configuration with a single southern inlet (Figure 4.14-.4.15). Identify the additional nitrogen load, compared to the threshold scenario detailed in the MEP Technical Report that would have to be removed to meet the nitrogen concentration threshold.
- Option 2. Maintain present conditions with a dual inlet scenario (Figure 4.16). Identify how dual-inlet flushing has affected the nitrogen concentrations previously defined in the current Pleasant Bay MEP Technical Report.
- Option 3. Potential single inlet system configuration. Identify conditions if the southern 1987 inlet closes and the northern 2007 inlet remains open.

The Alliance was also interested a re-run of the model under existing (2004) and build out loads.

Figure 4.15 Oblique view of Pleasant Bay and Nauset Beach prior to the 1987 inlet
(Source: Town of Chatham, Kelsey-Kennard air view, www.capecodphotos.com)

4.7.1 Limits on Performing these Scenario Runs

Scenario #1 did not require additional hydrodynamic analysis. Scenarios #2 and #3, however, required updating of the hydrodynamic model to define the threshold concentration at the sentinel locations because the 2007 inlet was created after the data that which was the basis for the 2006 MEP Technical Report was gathered. An in-depth assessment of the changes in bathymetry, tidal range, flow patterns, and tidal flow rates were carried out to refine the model to determine how the new inlet affected water quality throughout the Pleasant Bay system. The fieldwork to update this baseline data utilized the support from the US Army Corp of Engineers, the Pleasant Bay Alliance, Friends of Pleasant Bay, and a signed agreement with the Town of Chatham.

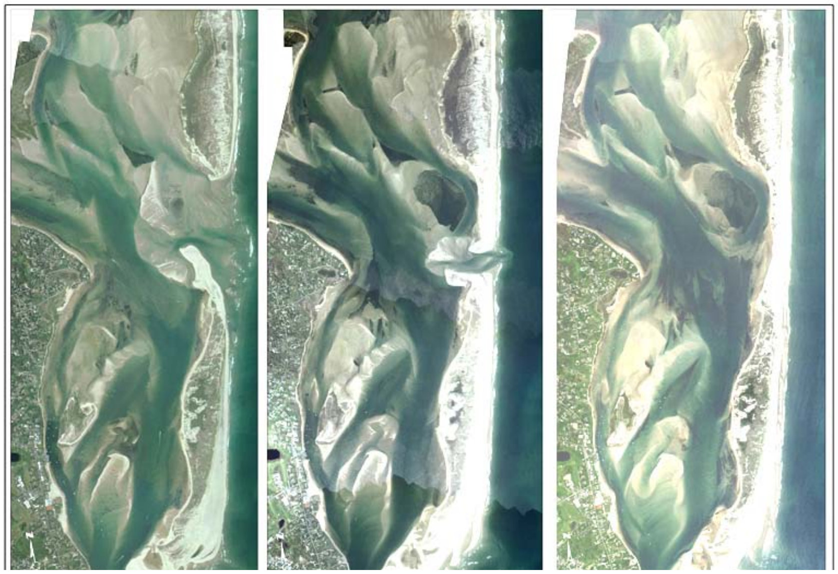


Figure 4.16 Sequence of Inlet Developments since April 2007 breach of Nauset Beach
Provided by the Town of Chatham, Kelsey-Kennard air view, www.capecodhootos.com

4.7.2 Scenario Runs

The final water quality model run, funded by the MassDEP Pilot Project was presented on the September 22, 2008 Technical Memorandum (Appendix P). The results of these scenario runs are briefly presented below.

- Option 1 (Pre-1987 single inlet configuration). This modeling scenario determined that the bioactive level of nitrogen was higher than the 0.16 mg N L^{-1} threshold concentration for bioactive nitrogen at the sentinel stations in Little Pleasant Bay (PBA-12), Upper and Lower Ryders Cove (PBA-03and CM-13, respectively) However, the secondary infaunal (animal) habitat threshold concentrations of 0.21 mg/L was achieved. Modeling of the single southern inlet under pre-1987 conditions required the modeler to estimate the watershed nitrogen loads during the 1950's when the greatest extent of eelgrass bed coverage existed in Pleasant Bay. With knowledge of where these eelgrass beds existed and the location of the inlet at its southern most extent, along with information of the tidal range, it was possible to estimate the 1950's sub-watersheds nitrogen loads by adjusting the tidal range at the inlet until the model simulated the nitrogen distribution across Pleasant Bay that was supportive of the eelgrass distribution patterns that were defined in the eelgrass distribution map of 1950. Using this approximation of conditions of the 1950's it was possible to consider existing nitrogen loads. The model assumed an 100% reduction of the attenuated septic load under current watershed loading conditions. This reduction "was intended to account for groundwater travel times and to offset other controllable loads (fertilizer use and stormwater runoff) that were unchanged from present conditions.

- Option 2 (Current 2007 dual inlet configuration). Under this scenario, the model determined that water quality improved significantly to a 0.158 mg/L concentration of biologically active nitrogen at the Little Pleasant Bay (PBA-12) sentinel location. As stated earlier, the 0.16 mg/L level has been determined to be restorative of eelgrass (Pleasant Bay Technical Memo Table 2 (Appendix P)). However, the improved flushing was insufficient in restoring water quality at the two Ryders Cover sentinel locations. The model indicated a bioactive nitrogen concentration of 0.19 mg N L^{-}

[1] average of the modeled concentrations for Upper Ryders Cove (0.229 mg N L^{-1}) and Lower Ryders Cove (0.150 mg N L^{-1}).

- Option 3 (Potential single northern inlet configuration). The model run predicted an improvement in water quality to Pleasant Bay, primarily due to its direct exposure to the Atlantic Ocean. However, this improved flushing was not significantly different from the dual inlet conditions at restoring water quality to the threshold concentration. This modeling was based on the dual inlet 2007 conditions, exemplified by the historical evidence from the 1850's when a similar northern breach ultimately caused the Nauset barrier beach to move landward toward its southern inlet, very similar to the occurrence that followed the 1987 breach.

Due to the timing of the completion of these model run results, coinciding with the termination of this project by EPA, the PBA was unable to discuss these results and the strategies they would pursue to address the load reductions for the restoration of water quality in Pleasant Bay. However, it is clear that these model results will generate questions among Work Group members and be the basis for additional model runs in the future, with the Alliance expressing its desire of becoming a clearinghouse for model runs that would have system-wide benefit that may not otherwise be pursued by an individual town.

4.8 Inter-municipal Wastewater Management Planning

4.8.1 Utilizing MEP Septic Load Reductions for Restoring Water Quality

As in all MEP Technical Reports, the percent reduction of the controllable septic load (Figure 4.7c) was the approach for reducing the nitrogen load from the watershed for habitat restoration at the sentinel locations in Pleasant Bay. Figure 4.18 identifies the percent septic load reductions recommended by the MEP Technical Report (Howes, B. et al., 2006), as one of many possible options, for each of the designated sub-watersheds to achieve the threshold concentration at the sentinel locations.

4.8.2 MEP Technical Report Septic Load Percent Reductions

Unlike the Popponesset Bay Watershed, the Pleasant Bay Alliance communities have decided to utilize the recommended percent septic load reductions that have been defined in the MEP Technical Report (Howes, B. et. al, 2006) for the sub-watersheds within their town borders (Figure 4.18). These reductions are the basis of any decisions regarding where and how much of an area within the watershed should be sewered, as well as what type of treatment plant would be the most environmentally sound and cost effective.

4.8.3 Town by Town Attenuated and Unattenuated Loads

To further assist the towns with its regional focus on wastewater management planning for the Pleasant Bay Watershed, the PBA requested the Cape Cod Commission to calculate the attenuated and unattenuated loads contributed from the four towns to the Bay's 95 sub-watersheds. While the towns' wastewater management plans are at various stages, the PBA Work Group continues to pursue its regional coordination approach to TMDL implementation. The attenuated and unattenuated loads presented in Table 4.9 and Figure 4.17 for the four towns under current and build out conditions, under current zoning, should further future discussions concerning an allocation of responsibility and costs for the reductions required from the watershed as a whole. The Cape Cod Commission member expressed his hope that these estimates would lead to a "fair share" allocation of responsibility for the reduction of nitrogen loads and cost savings.

Table 4.9 Unattenuated and Attenuated Loads to Pleasant from Brewster, Chatham, Harwich, and Orleans under existing and build-out conditions (Source: Howes, B. et al., 2006)

			Nitrogen Load (kg/y)							
			Existing				Built -out			
Town	**Area (acres)**		**Unattenuated**		**Attenuated**		**Unattenuated**		**Attenuated**	
Brewster	3,529.82	16.34%	7209	14%	6404	14%	8612	13%	7598	13%
Chatham	6,458.67	29.90%	17900	36%	17079	37%	20443	32%	19583	33%
Harwich	2,789.30	12.91%	8673	17%	8478	18%	11560	18%	11338	19%
Orleans	8,821.93	40.84%	16112	32%	14655	31%	23691	37%	21679	36%
Total	21,599.72	100.00%	49894	100%	46616	100%	64306	100%	60198	100%

At the November 2006 Work Group meeting it was expressed that each town should also look at present and projected loads in each sub-watershed in terms of the controllable load (wastewater discharge permits, new septic systems, fertilizer use, etc.) to determine if there are immediately identifiable components that could be managed to achieve the TMDL. Agreement on the loads reductions from each town would be an important first step.

Concerning the allocation of responsibility for the reduction of nitrogen loads among the PBA communities, the Alliance had two recurring themes at their December 2006 meeting:

1. The need to know each town's attenuated load in each subwatershed under current and build out conditions. While the MEP Technical Reports provided a parcel-based approach for calculating nitrogen loads within each sub-watershed and the watershed as a whole, town-specific loads were not calculated. Without this information, a discussion on allocating loads would be impossible.

2. The desire for MassDEP to provide an allocation of assimilative capacity by town, which would represent each town's share of the TMDL for a sub-embayment, and any average up to their attenuated load for that sub-embayment would be the portion the town is responsible for removing. MassDEP has not addressed this approach, primarily because the MEP Technical Report and the TMDL that is based on it's load calculations reflects only (a) one scenario of how the threshold concentrations could be met and (b) it provides a better basis for inter-municipal dialogue for watershed-wide planning and TMDL implementation.

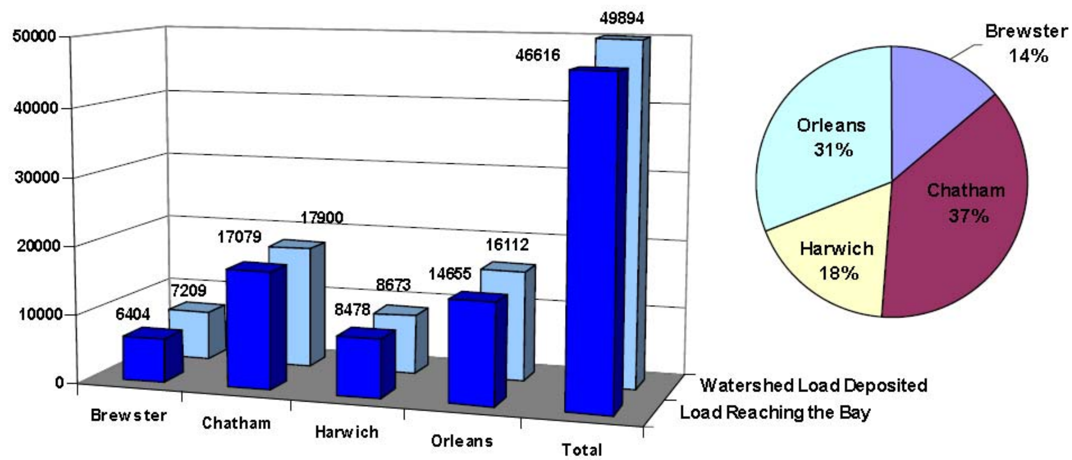


Figure 4.17 Bar graph of the unattenuated nitrogen load deposited to the watershed and the attenuated nitrogen load that reach the Bay from each of the four towns under existing conditions. Pie Chart of the percentage of the attenuated load that reaches the Bay from each town under existing conditions (see Table 4.9)

4.9 Inter-municipal Planning and Implementation

The PBA's Work Group continues to express interest in pursuing joint modeling scenarios for use by the towns in their CWMP decision-making. Also, as CWMPs are developed and implemented the scenarios will provide useful data for collaborative wastewater management planning for the restoration of water quality in Peasant Bay Watershed. As expressed recently at its January 08, 2008 meeting, the most telling scenario will be the outcome from the sewering proposals identified as the third alternative in the Chatham and Orleans' CWMPs. At this meeting, MassDEP agreed that the emphasis should be to achieve the threshold concentrations at the sentinel stations, and on how well the proposals collectively address the nitrogen threshold concentration. According to MassDEP, compliance will be based on steps the towns take to implement plans that are supported by MEP Linked model runs showing that threshold concentrations being met, even though meeting those concentrations may occur over a very long term.

The Towns of Chatham and Orleans have taken the lead among the PBA for their respective communities in the CWMPs that address the nitrogen loads affecting Pleasant Bay. The Town of Chatham is the furthest along of any MEP community. The CWMP has been approved by the Secretary of Energy and Environmental Affairs and is being reviewed by the MassDEP as the basis for approving a groundwater discharge permit for Chatham. Orleans is in its final phase and will be seeking public comment on its draft plan prior to submitting it to the state's MEPA Unit for approval by the EOEEA Secretary.

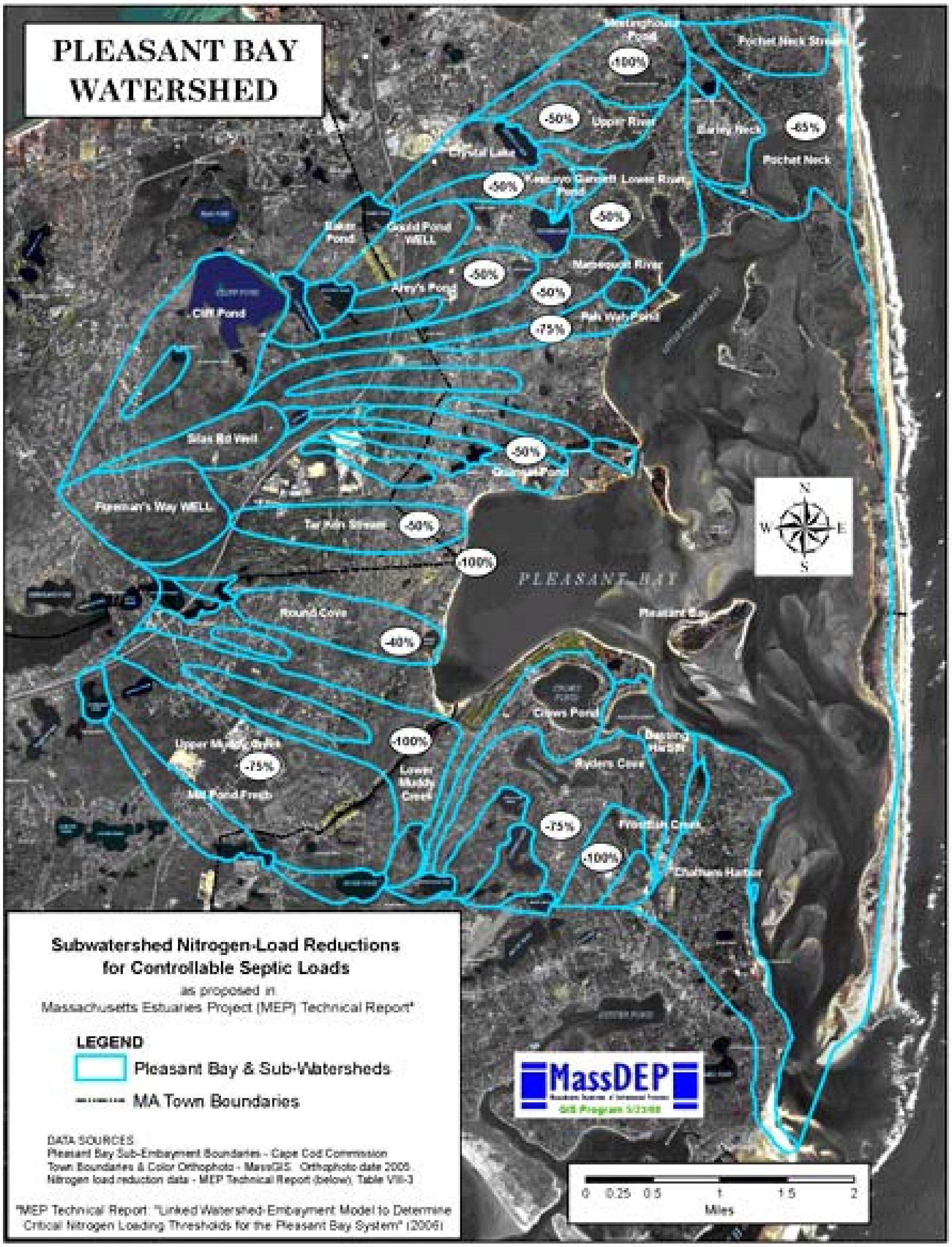


Figure 4.18 Percent reduction in septic load recommended for each of the designated Pleasant Bay embayments as defined by the MEP Technical Report
(Howes, B. et al., 2006)

4.9.1 Regional Implications of the Orleans CWMP

At the time this report was prepared, the Town of Orleans drafted a proposal for public discussion that identified locations for sewering within the Pleasant Bay watershed (Figure 4.19). The highlighted green locations in Figure 4.19 are one of several scenarios under consideration for sewering. Currently, the draft plan includes a phased-construction approach with the possibility of sharing use of the Tri-Town wastewater facility (currently for septage treatment) with its neighboring towns - presumably to help defray the annual operating costs. A phased, deferred construction option also provides the opportunity to accommodate future flows from its neighbors at a later date when their CWMPs are completed so they can address the costs and benefits of a shared regional facility. The draft CWMP suggests the opportunity of participating with the Town of Brewster to address its 14% attenuated nitrogen load (Table 4.8) to Pleasant Bay in "a Pleasant-Bay focused regional solution…" also with the potential of including wastewater flows from East Harwich and North Chatham.

In view of the fact that the CWMPs by the four towns are in various phases of completion with two near completion and/or approval, the phasing of CWMP implementation by the four towns has some merit. For the Town of Orleans it provides the potential benefit of accommodating wastewater flows from neighboring towns whose planning is still underway several years behind Orleans's efforts. Secondly, phasing has the added future benefit of synchronizing "watershed load reductions with other towns sharing a given watershed."

4.9.2 Regional Significance of the Economies of Scale Study

In recognition of the difficulties of implementing a regional approach that addresses the economies of scale in the construction and operation of a regional facility, the Town of Orleans in collaboration with the Towns of Harwich, Brewster, and Eastham embarked in a Cape Cod Water Protection Collaborative funded study "Economies of Scale Associated with Regional Wastewater Infrastructure and Appropriate Cost Sharing Formulas" that is nearing completion When completed, this study will quantify the potential cost savings associated with regional wastewater treatment and disposal facility One of the two case studies evaluated, which should be of interest to the PBA, addresses a prospective treatment facility located in the Pleasant Bay Watershed near South Orleans. This facility would address the Pleasant Bay load reductions from the towns of Orleans, Harwich, and Brewster. Most importantly, this study would provide a load allocation for each town and the projected cost savings, using several formulas that address cost sharing (see: http://www.barnstablecounty.org/documents/Application2--EconomiesofScale.pdf).

As stated in the grant proposal, justification for this study was clear.

> "In the absence of watershed management districts or other regional entities charged with developing regional wastewater infrastructure, there is the strong possibility that Cape Cod towns will view town-owned facilities as the primary options. Regional facilities may have benefits, but they also entail significant practical and political hurdles. It would be an appropriate use of CCWPC grant funds to document the cost savings to towns participating in a regional wastewater facility, to help overcome some of the political hurdles to joint facilities. There are 5 principal cost items in wastewater infrastructure: 1) collection, 2) transport to the treatment plant, 3) treatment, 4) transport to the disposal location, and 5) disposal. At the scale of all Cape Cod towns, the economies of scale in wastewater treatment are significant; it might cost two or three times as much to treat a gallon of wastewater at a small single-town plant than it would at a larger regional facility. Offsetting these cost benefits are added transport costs. Complicating the situation is the fact that, given the scarcity of large sites for effluent disposal, one town might benefit significantly from disposal capacity in a bordering town. Conceptual-level cost estimates

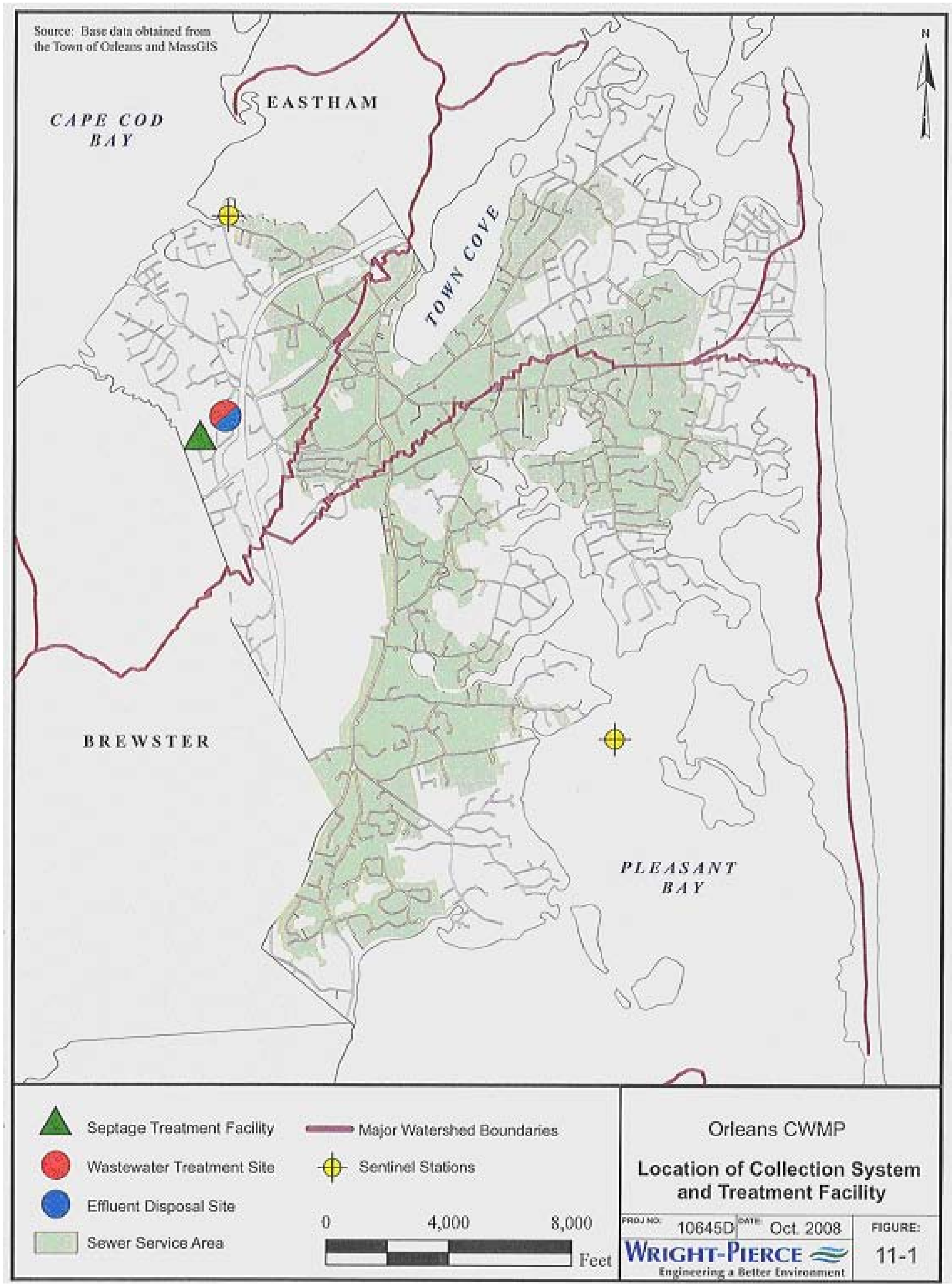


Figure 4.19 Town of Orleans CWMP Proposal for Public Discussion identifying locations within the Pleasant Bay Watershed for sewers

Courtesy of Town of Orleans.

will be prepared to explore the cost benefits of regional treatment plants in two locations: 1) at the Tri-Town site in Orleans serving portions of Orleans, Eastham and Brewster; and 2) at a site in South Orleans or the easterly section."

Nitrogen Trading Potential - When completed this study provides the potential to establish a unit cost for future nitrogen trading. The allocated costs are expected to be transformed into a cost per pound of nitrogen removed. These unit costs would then serve as a basis for future nitrogen trading, as well as to establish benchmarks for cost comparison and evaluation against each town's CWMP recommended cost projections. Pleasant Bay Alliance members are hopeful that this study will provide cost savings that would sway local decision makers toward a regional inter-municipal approach to sewering.

4.10 Lessons Learned for MassDEP's Future Planning

4.10.1 Possible Management and Permitting Mechanisms

Based on MassDEP's current policies and regulations, what new management and permitting mechanisms would you recommend to address the EPA mandated TMDL load reductions for Pleasant Bay?

- Codification of point of compliance – through the Working Group the Alliance communities have learned about the policy direction under discussion by MassDEP regarding point of compliance. MassDEP's codification of this approach through a policy guidance or similar document has been requested.
- Clarification on the nature of approving CWMPs would also be helpful and, specifically, clarity on the level of detail that would be provided in a groundwater discharge permit to a town or district.
- Monitoring protocol and reporting procedures – The Alliance has requested clarification on monitoring requirements, protocols and reporting procedures necessary to demonstrate TMDL compliance.
- Policy guidance is needed to address how or if TMDLs may be modified in light of changes in the inlet barrier beach configuration. It also would be important to know if a town's CWMP could be approved without a model scenario that showed concentrations being met throughout the system. This latter question relates to the fact that towns are at different stages of the planning process.

4.10.2 Monitoring and Permitting Compliance

The following summarizes the latest information concerning monitoring and compliance issues as they are being developed by MassDEP.

MassDEP is currently thinking that compliance points will reflect milestones in the phased implementation of approved CWMPs. On-going monitoring will be required, but MassDEP will not be looking at restoration targets as points of compliance. However, MassDEP will evaluate monitoring results for trends leading to water quality improvement and habitat restoration.

The current position is based on the understanding that CWMPs are built on the model that indicates if you undertake measures that are intended to lead to a level of nitrogen loading, then the restoration should follow. It is fair to base compliance on what MassDEP is asking the towns to undertake.

Specifics of the monitoring requirements still need to be developed. Eelgrass monitoring will be done by the state. Benthic monitoring will likely be on a five-year schedule. Water quality monitoring will be continued, but could be scaled back, and adequate pre- and post facilities monitoring requirements would need to be determined. We discussed the pros and cons of suspending monitoring prior to the baseline period versus keeping it going at a scaled back rate.

Monitoring is likely to be long-term because evidence of restoration may well extend beyond the 20 year planning horizon for CWMPs. One scenario is that the water quality concentrations are achieved but eelgrass does not regenerate. Other factors would need to be considered. The PBA discussed ongoing research on eelgrass restoration, and the possibility that if water quality targets are met, then eelgrass restoration could be undertaken. (5-23-07)

4.10.3 Local or Regional Obstacles for Watershed-Based TMDL Implementation

- The Bay is a large and intricate estuarine system with a watershed encompassing four towns. The nature of the system, the number of sub-embayments with shared sub-watersheds, and the number of towns involved adds layers of complexity to the planning process.

- One hurdle in facilitating coordinated action is the differences in the timelines for the four towns' respective wastewater management planning efforts. Because the towns are at different stages in the planning process, their needs for information and joint analysis differ. Also, the level of public awareness and familiarity with the issues of nitrogen loading and facilities planning vary for each town.

- Although not necessarily an obstacle, the dynamic nature of the inlet and barrier beach formation poses a challenge in terms of understanding and monitoring baseline conditions.

4.10.4 Role of Community-Based Outreach and Planning in Wastewater Mitigation

- Each of the four towns manages a process to provide public input into their respective wastewater management plans. Local input through advisory committees, public meetings, media coverage and presentations to local committees and boards plays an important role in building awareness and understanding of the facilities planning process.

- Implementation actions such as facilities development are expected to take place within towns or between groups of towns. The Alliance is not expected to undertake implementation actions other than for monitoring, compliance reporting, modeling, public information, and development of coordinated responses or strategies.

- The Alliance incorporates public outreach in nearly all of its wastewater planning initiatives. The work group facilitated by the Alliance brings together community representatives of different disciplines to discuss issues, share information, and develop strategies. Many of the work group participants are active in local and regional environmental organizations. The Alliance has also hosted public forms for the release of technical information, and input on TMDL development. Public forums will also be planned for the fertilizer management study and the Muddy Creek resource assessment noted above.

- The Alliance also publishes Citizens Guides to Estuarine Protection which are subwatershed based publications designed to provide essential information on watershed physical features and functions, as well as the implications of nutrient loading for ecosystem health.

4.11 Final Thoughts

The Pleasant Bay Alliance continues to address its mission, through its updated five-year plan, in its role of bringing communities together to address the nitrogen load reductions identified in the MEP Technical Report. Because the CWMPs for each of the four towns are at different stages of development and implementation, the PBA clearly has an important role in promoting its regional approach toward wastewater management planning and implementation. Town-by-town efforts alone cannot address the watershed-wide nitrogen reductions required to restore and sustain the dependent fragile ecosystems of the Pleasant Bay embayment system - a significant natural resource that been listed by the State as core habitat in its BioMap and as an Area of Critical Environmental Concern. As such, the PBA is uniquely positioned through its memorandum of agreement to promote the collaboration among the towns. However, there will be CWMPs that will undergo several iterations before one succeeds in addressing the resource protection needs of an embayment system that is affected by the changing configuration of its barrier beach. As defined by the PBA Work Group scenario runs, any plan must consider the possible changes this barrier beach will undergo in the future and how each change affects water quality; including the worse case, of an embayment without an inlet that flushes nitrogen from this system to the Atlantic. It appears that the wastewater planning required to achieve the restoration and continued protection of this regional resource will continue long into the future through the PBA's monthly Work Group meetings. Similar collaborative efforts could easily be duplicated among coastal communities sharing a coastal watershed elsewhere for the protection of fragile embayment systems that are vital not only for their recreational uses but also for the habitat they provide as breeding ground and nursery to many dependent shellfish and commercial fisheries.

Chapter 5: Municipal, Regional, and State Accomplishments - Public and Private

5.1 Inter-Municipal CWMP Coordination and Planning

Pleasant Bay Resource Management Alliance

The PBA (http://www.pleasantbay.org/) has served to spearhead and coordinate among the towns sharing the Pleasant Bay Watershed a number of initiatives for the protection of Pleasant Bay, including CWMPs, nitrogen trading, and research studies:

- Coordinated local funding and input into the system-wide assessment of Pleasant Bay under the MEP, and coordinated local input throughout the process of developing TMDLs;
- Convened a monthly work group of local regional and state officials to discuss the status of local wastewater planning and strategies for regional cooperation;
- Discussed at the work group meetings coordination of planning timelines, requirements for monitoring and compliance with TMDLs, and needs for additional data made available through modeling and other analyses;
- Sponsored SMAST Linked model rounds and other analyses that support a greater understanding of (1) how physical changes in the system could affect nitrogen loading and reduction targets and (2) the combined system wide effects of selected local actions;
- Managed two projects relevant to multi-town nutrient reduction efforts: (1) watershed wide fertilizer management study to determine whether it is feasible to obtain significant reductions through management of this nitrogen source; and (2) a study of the resource impacts, permitting strategy and cost allocation methods associated with re-installing a dike in Muddy Creek for purposes of nitrogen attenuation;
- Individual alliance communities have implemented policy and regulatory changes to address nitrogen loading as described in the preceding section.

5.2 Municipal Accomplishments

Regulatory and zoning measures have been underway for some time in the Towns of Mashpee, Barnstable, Sandwich, Brewster, Chatham, Harwich, and Orleans. The zoning, regulatory, and planning initiatives adopted by these communities are briefly outlined below; each addressing one or of the measures that were adopted for the protection of the embayments of this case study: Popponesset Bay, Three Bays, and Pleasant Bay.

5.2.1 Town of Mashpee

Mashpee has taken a number of planning, regulatory and zoning actions to mitigate the impacts from excess nitrogen loading to its estuaries. These are discussed below.

5.2.1.1 Wastewater Management Planning

The Town of Mashpee began Nutrient Management Planning in 1997 with monitoring of nitrogen levels in Popponesset Bay and Waquoit Bay. This was followed by an assessment of the data. The Town of Mashpee expanded its planning in 1999 to encompass all the ground-watersheds the town shares with its neighbors, including Popponesset Bay, Hamblin-Jehu Pond, and Waquoit Bay. The town's share with other, out-of-town, estuaries is negligible.

When the MEP began in 2000, MassDEP recommended that Mashpee should postpone its planning until the MEP Technical Reports for its embayments were completed. In this way, the plan would utilize the latest science-based findings on nitrogen pollution and the recommended nitrogen reductions to restore surface water quality. Based on the findings of the 2004 Popponesset Technical Report and the TMDL that followed, Mashpee renewed its CWMP efforts in the Fall of 2006 with the Sewer Commission taking the lead with the completion of the Stage 1 Needs Assessment in April 2007.

As of May 2008, when this report was undergoing completion, the Town of Mashpee had completed three of the four steps leading to the Draft CWMP.

5.2.1.2 Zoning

(see: http://www.ci.mashpee.ma.us/Pages/MashpeeMA_Planning/2007ZoningBylaws.pdf)

Cluster Development Bylaw (§174-47) **-** Amended by Town Meeting at its October 2006 meeting encourages **"**…the preservation of open space, to reduce the impact of new development of Town's water quality and natural resources." Cluster subdivision, with a minimum of 50% open space, is mandatory for subdivisions of 5 acres or more.

Water Quality Report Bylaw (§174-27) **-** Amended by Town Meeting at its October 2006 meeting, requires developers of subdivisions located within the groundwater recharge zone of any great pond or bay or other surface water body over one (1) acre to prepare a water quality report of potential project impacts on surface- and ground water quality as well as what mitigation efforts the developer will undertake to reduce or mitigate those impacts. The by-law specifies the use of MEP reports and TMDL targets and assumes the following phosphorus and nitrogen loading rates:

- **Lawns -** 1.08 pounds nitrogen and 0.0069 pound phosphorous per one thousand (1,000) square feet per year, with 5000 sq. ft. average lawn size assumed per lot in a single-family subdivision.

- **Stormwater -** 1.5 mg/l nitrogen for road runoff, 0.75 mg/l for roof runoff and 0.072 mg/l for natural areas; or alternately, nine-hundredths (0.09) pound nitrogen per road mile per day.

Stormwater Management Bylaw (§174-27.2) **-** Requires any new residential or non-residential development requiring either subdivision approval, a special permit, plan review, or a building permit for a building over one thousand (1000) square feet in area to provide a system of stormwater management and artificial recharge of precipitation. Stormwater should be designed to achieve the following purposes: prevent untreated discharges to wetlands and surface waters; preserve hydrologic conditions that closely resemble pre-development conditions; reduce or prevent flooding by managing the peak discharges and volumes of runoff; minimize erosion and sedimentation; result in no significant degradation of groundwater; reduce suspended solids, nitrogen, volatile organics and other pollutants to improve water quality; and provide increased protection of sensitive natural resources. For new single or two-family residences, stormwater runoff from rooftops, driveways and other impervious surfaces shall be routed through vegetated water quality swales or as sheet flow over lawn areas or to constructed stormwater wetlands, sand filters, organic filters and/or similar systems capable of removing nitrogen from stormwater. For new subdivision roadways or for lots occupied or proposed to be occupied by uses other than single or two-family homes, a stormwater management plan is required, which provides for artificial recharge of precipitation to groundwater through site design that incorporates natural drainage patterns and vegetation and through the use of constructed (stormwater) wetlands, bioretention facilities, vegetated filter strips, rain gardens, wet (retention) ponds, water quality swales, organic filters or similar-site-appropriate current best management practices capable of removing significant amounts of nitrogen and other contaminants from stormwater.

In addition, the Planning Board's Consulting Engineer, Charles Rowley, completed a report in May of 2006 entitled "Stormwater Report on Runoff to Mashpee and Santuit Rivers from Public Ways."

5.2.1.3 Regulations

Board of Health - Regulatory requirement for denitrifying systems (on-site wastewater disposal systems) that reduce nitrogen discharges to 10 mg/L, measured at a monitoring well down-gradient from the leaching facility 10" from the lot line, compared with 36 mg/L at the leaching area from a conventional septic system for discharges with design flows greater than 600 gallons per day (six bedrooms or more) (see: http://www.ci.mashpee.ma.us/Pages/MashpeeMA_Health/index) .

The Conservation Commission Wetland Regulations - Amended with detailed design specifications to reduce nitrogen loading from lawns (new and renovated). They were also amended to set inland/coastal water quality standards in its Regulation 32 with site-specific limits necessary to control accelerated or cultural eutrophication (see: http://www.ci.mashpee.ma.us/Pages/MashpeeMA_Conservation/index).

Planning Board Rule on Lawn Area - The Planning Board has obtained regulatory commitments from developers to limit lawn size in new developments, usually to 1000 sq. ft., based on its Water Quality Report zoning by-law. However, these are virtually impossible to enforce (see: http://www.ci.mashpee.ma.us/Pages/MashpeeMA_Planning/regs).

Zoning and Conservation Regulations on Denitrifying Systems - Both zoning and conservation commission regulations require denitrifying systems in other circumstances. As of autumn 2006, approximately 250 denitrifying systems were approved and 228 installed, more than in any other town on Cape Cod.

5.2.2 Town of Barnstable

Efforts by the Town of Barnstable to protect its inland and coastal resources were recognized in 2002 when EPA New England awarded the town the Environmental Merit Award for growth management and environmental protection initiatives to protect the town's fragile environment, while addressing the importance of providing affordable housing. The Merit Award recognized the town's newly adopted two acre zoning in environmentally sensitive areas (about one half of the town); a nitrogen management ordinance to promote innovative and alternative wastewater disposal systems; a smart growth ordinance that allows for higher-density zoning in the Hyannis' business district (a sewered area); a comprehensive building cap; cluster zoning for subdivisions; and an affordable housing plan. The zoning and regulations cited below can be seen at http://town.barnstable.ma.us/TownCouncil/Ba2043-0.pdf.

5.2.2.1 Zoning

Resource Protection Overlay District (Ch. 240, §36) - This overlay residential zoning district was adopted by the Town Council on October 26, 2000 to require a minimum, buildable lot area of 87,120 sf (two acres) for the purpose of reducing future nitrogen loading to the watershed recharge areas to the Centerville River, Popponesset and Shoestring Bays, and the Three Bays estuaries; together with areas dependent upon private well water supplies. Collectively, this residential overlay district covered nearly one half of the town. See Appendix U for details.

Site Plan Review (§ 240-39 (4) - Barnstable's Site Plan Review Regulations (j) state, in part that: all surface water runoff from structures and impervious surfaces shall be disposed of on-site, but in no case shall surface water drainage be across sidewalks or public or private ways. In no case shall surface water runoff be drained directly into wetlands or water bodies (except for drainage structures in place as of the effective date of this regulation). All drainage systems shall be designed to minimize the discharge of pollutants by maximizing appropriately designed vegetated drainage channels and sedimentation basins that allow for adequate settling of suspended solids and maximum infiltration (with due regard to the design constraints). Dry wells, leaching pits and other similar drainage structures may be used only where other methods are not practicable. Subject to ambient surcharge conditions, roof runoff shall be recharged to the ground via a system of dry wells and/or infiltration systems. Nontoxic roof materials shall be used to minimize the leaching of toxic materials to the groundwater

5.2.2.2 Regulations

Board of Health (BOH) Regulations - An Interim Board of Health Regulation was adopted on 6/30/2008 to protect saltwater estuaries (Article XV Protection of Saltwater Estuaries §360-45) by limiting the allowable discharge of sanitary sewage from residential buildings to "... not exceed 440 gallons per 40,000 square feet of lot area." This means an approved lot with less than 30,000 square feet is allowed a discharge of 330 gallons. Simplified, this corresponds to the number of bedrooms, using the Title 5 standard of 110 gallons per bedroom (Appendix T). Some other protective BOH regulations for the embayments are listed below.

- Ch.360: On-Site Sewage Disposal Systems - To protect groundwater, freshwater, wetlands and water course from contamination by septic waste.
- Article I (§360-1): Location of Components with respect to water bodies.
- Article III (§360-3): Floodplain Sewage Regulation
- Article VI (Ch. 360): Groundwater Protection – To protect groundwater from nitrate contamination (§360-12), also with (§360-13) - to connect to public sewers when available.
- Article X Ch. 360: Monitoring of Alternative Technologies and Article XIII Ch. 360: Innovative and Alternative Systems - identifies nitrogen reduction requirements in proximity to fresh water and marine water resources and to other sensitive environmental receptors.
- Article XV §360-45: Protection of Saltwater Estuaries (Adopted 6-30-2008)

Other Regulations and Districts - Town Regulations addressing Private Docks and Piers (Ch. 703) contain a section that deals with the issue of "nutrient-laden sediment" (§703-1. E.). Several additional Overlay Districts are in place to protect resources: Dock and Pier Overlay District (Ch. 240, §37) and Temporary Recreational Shellfish Area and Shellfish Relay Overlay District (Ch. 240, §37.1), which went into effect on 4/3/2008 and will be in effect for 18 months during which time the 1990 Coastal Resource Management Plan will be updated.

The Town of Barnstable Regulations are listed on the town's website as Ordinances/E-Code. The site is searchable using key words or Article number references.

5.2.2.3 Planning

District of Critical Planning Concern - A town-wide DCPC was adopted in February 2001 by the Town Council in support of a resolution to manage residential growth and to encourage affordable housing over nearly 60 square miles. The nomination stated as a goal: "to address the rate of residential development", which, if continued at its present growth rate "would have serious consequences for municipal infrastructure" and would "move the town further away from its goal of affordable housing stock." The intent of a DCPC, as described in the Cape Cod Commission's Regional Policy Plan, is to provide a "time out" from development, in order for a town to prepare and implement new measures that address its stated purpose for the DCPC. In Barnstable's case, the suggested guidelines for development included an annual residential building permit cap ordinance with a preference for affordable housing, and a general ordinance and board of health regulation "limiting nitrogen discharged from new residential subdivisions (e.g. shared denitrifying system requirements)" needed to maintain good water quality." The Barnstable DCPC was designated, among other reasons, to protect the local and regional water supply, and the sole source aquifer, from contamination occurring from excessive development (specifically, from associated nitrogen contamination primarily caused by septic systems), and also to protect coastal embayments (from nitrogen contamination), which threatens to adversely impact local shellfishing in the embayments. The nomination also supported the need to remediate water quality in [coastal] embayments. For more information on this DCPC, please consult http://www.capecodcommission.org/DCPC/designated.htm

Capital Improvement Plan - Barnstable's 2008 Capital Improvement Plan includes a commitment by the Town to fund nitrogen management planning and a nitrogen management program over five years. In 2004, the Town received State Revolving Fund (SRF) funding to cover approximately 2/3 of the estimated cost ($3.1M) of the Nutrient Management Plan (NMP). The Town Council started to appropriated funds to cover the SRF Loan in 1998 ($200,000); $250,000 in 2001; and $1,700,000 in 2002. In August 2008, the Town submitted a 2009 Project Evaluation Form (PEF) to the SRF for future funding (see: http://www.town.barnstable.ma.us/TownManager/08CIP/2008CIP.pdf).

Wastewater Management Planning - The town's Comprehensive Wastewater Facilities Plan (CWFP) was approval by MEPA and the Cape Cod Commission in October 2007. The CWFP addressed the Town's immediate wastewater concerns, and future needs to protect and restore resources using the Nutrient Management Program. The adaptive implementation management approach is a key factor in dealing with long-term environmental restoration programs; an approach that allows the use of the newest research and technology available. Information is available on the following websites:

- http://town.barnstable.ma.us/PublicWorks/WaterPollutionControl/Final%20Wastewater%20Facilities%20Plan/ExecutiveSummary.pdf
- http://www.capecodcommission.org/regulatory/DRIdecisions/BarnstableWWFPfinaldecis.pdf

Barnstable Local Comprehensive Plan (LCP)

Relevant goals and action items in the Local Comprehensive Plan for Barnstable are listed below (see: http://town.barnstable.ma.us/GrowthManagement/ComprehensivePlanning/LCP/CompPlan08/LCP.asp)

Goal: Improve the shellfishing and recreational uses of the Bays. To achieve this objective the LCP calls for the implementation of the Nitrogen TMDL's developed for Three Bays by MA DEP, and calls for Town of Barnstable to work with the Towns of Mashpee and Sandwich to implement necessary shared watershed wastewater management and other nitrogen reduction policies.

Strategy: Improve flushing at the bays. Action: Dredge the area in Barnstable southern embayments (North, West and Cotuit Bays) and inlets to improve the flushing in the bays.

> *Action:* Limit new piers, especially in the Cotuit Narrows, to prevent reduction of flushing flow and impacts on shellfishing.
>
> *Goal 2.2.3 Maintain and improve coastal water quality to allow shellfishing and recreation as appropriate, and to protect coastal ecosystems which support shellfish and finfish habitat with the ultimate goal of restoring and maintaining ecological integrity in our coastal waters.*
>
> *Action 2.2.3.1* Continue, through the Massachusetts Estuaries Program (MEP), Town, County and Commonwealth mapping of recharge areas for all major estuaries and embayments to identify areas where development and land use have the most impact on coastal water quality. This information is available through the Town's GIS system as it is developed.

Strategies: Through the MEP, a long-term coastal resource water quality monitoring program is underway in Barnstable. The Town will continue to participate through the completion of the project in Barnstable.

The Town should determine a course of action to comply with the Total Maximum Daily Loads (TMDLs) established as part of the Massachusetts Estuaries Program (MEP).

Action 2.2.3.2 Protect environmentally fragile areas and reduce nitrate nitrogen loading in marine recharge areas.

Strategies:
Reduce impacts in FEMA A and V zones by amending the Zoning Ordinance to require floor area ratio requirements and impervious area limitations to allow development and redevelopment that does not create large impervious areas that interfere with the flood mitigating function of natural resources.

Adopt a town-wide regulation to limit impervious surface area.

Goal 2.6.1 Minimize wastewater contamination of water resources from private or public wastewater management systems to improve drinking water quality, with the ultimate goal of achieving an untreated water supply, and to improve the ecological integrity of streams, ponds and coastal embayments using all available data including Massachusetts Estuaries Program (MEP) data.

5.2.3 Town of Sandwich

Water Quality Advisory Committee - During the final year of the Pilot Project, the town representative from Sandwich was successful in having the Town recognize its responsibility to address the nitrogen load from Sandwich, as identified in the TMDL report affecting the Popponesset Bay. As a result, the Water Quality Advisory Committee (WQAC) was appointed in 2007 to review and provide its recommendations to the Board of Selectmen on all MEP-related matters. This committee includes a member from the Board of Health, Planning Board, Conservation Commission, and the Board of Selectmen. Prior to this endeavor, the Sandwich Health Director’s role at Pilot Project meetings was limited. The WQAC is currently taking the lead and is currently in the process of hiring a consultant with its reviews and recommendations of the Pilot Project.

5.2.4 Town of Brewster

In 2007, Brewster for the first time officially joined the Pleasant Bay Alliance and entered-up a membership assessment to address water quality related issues that have affected Pleasant Bay from its town borders. It also appropriated funds to contract with professionals to initiate water-planning efforts and assist in the development of a CWMP.

5.2.4.1 Zoning

Water Quality Protection Bylaw (Chapter 170) - Brewster is proposing revisions to its Ground Water Protection District Overlay zoning bylaw to restrict hazardous land uses and tighten permitting processes. Among this bylaw’s many purposes, is to “complement the Commonwealth's Department of Environmental Protection regulations governing groundwater protection and the Commonwealth’s efforts to protect surface and coastal waters and to prevent temporary and permanent contamination of the water resources of the Town.” This bylaw has reserved an undefined section for the protection of

Pleasant Bay for future consideration by the Town (Revised 7/26/2008) (see: http://www.town.brewster.ma.us/content/view/616/29/)

5.2.4.2 Planning

Nomination of a District of Critical Planning Concern - To prevent grandfathering and further development within the watershed until a new bylaw is adopted and approved by the Cape Cod Commission for the protection of groundwater as drinking water and for the protection of Pleasant Bay. (http://www.town.brewster.ma.us/images/stories/dcpc_nom_final3.pdf). Nomination accepted by the Cape Cod Commission.

5.2.5 Town of Chatham

5.2.5.1 Zoning

The Town of Chatham Protective (Zoning) Bylaw contains several Overlay Regulations that address the issue of nutrient impacts on the environment. They are listed below.

Conservancy Districts – "Conservancy Districts are overlay districts intended to:
- Preserve and maintain the ground water supply on which inhabitants depend;
- Protect the purity of coastal and inland waters for the propagation of fish and shellfish and for recreational purposes;
- Protect the public health and safety;
- Protect persons and property from the hazards of flood and tidal waters which may result from unsuitable development in or near swamps, ponds, bogs and marshes, along watercourses or in areas subject to flooding, extreme high tides and rising sea level;
- Preserve the amenities of the Town and to conserve natural conditions, wildlife and open space for the education and general welfare of the public."

Flood Plain District – "The purposes of the Flood Plain District are to protect the public health, safety, and general welfare, to protect human life and property from the hazards of periodic flooding, to preserve the natural flood control characteristics, and the flood storage capacity of the flood plain, and to preserve and maintain the ground water table and water recharge areas within the flood plain."

Water Resource Protection District – "The purpose of the Water Resource Protection District (WRPD) is:

- To promote the health, safety, and general welfare of the community by ensuring an adequate and quantity of drinking water for the residents, institutions, and businesses of the town of Chatham;
- To preserve and protect existing and potential sources of drinking water supplies;
- To conserve the natural resources of the Town; and
- To prevent temporary and permanent contamination of the environment."

The full text of these bylaws is available on the Chatham Community Development website http://www.chatham-ma.gov/Public_documents/chathamma_CommDev/ZBylaw2005.pdf

5.2.5.2 Regulations

Board of Health - Nitrogen Loading Regulation (Appendix V) The Chatham Board of Health enacted an Interim Nitrogen Loading Regulation in 1991 that limited nitrogen loading on a parcel to 10 ppm. This regulation has undergone a number of subsequent revisions, the most recent in 2006, including a shift away from the 10 ppm drinking water standard as being none protective for estuarine systems. In 2004, the Board of Health voted to declare the entire Town an "Area of Nitrogen Concern".

The current regulation limits the flow of wastewater to no more than 440 gallons per acre of lot area (excluding wetlands). The regulation applies to new commercial development under 10,000 gpd (Title 5 flow); existing commercial development with a total Title 5 sewage flow of under 10,000 gallons per day where an addition or a change in use is proposed that will increase the sewage flow over the existing flow but still be less than 10,000 gallons per day; subdivisions or Open Space Residential Developments (i.e. so-called "cluster" subdivisions) creating three (3) or more parcels, regardless of existing dwelling units; construction of multi-family and single family dwellings; and alterations or additions to existing dwellings where a new bedroom is being added.

Additional provisions:

- This regulation shall not prohibit the construction of a two (2) bedroom house on any vacant lot providing said lot is not in a nitrogen Sensitive Area, as defined in 310 CMR 15.215 (http://www.mass.gov/dep/service/regulations/310cmr15.pdf) .
- No building permit, foundation permit, special permit, or plumbing permit shall be issued for any of the projects described in Section 4 above until a Sewer Entrance Permit or Disposal System Construction Permit has first been obtained, unless the Board of Health, or its agent, determines that the existing sewage disposal system is adequate, including that the system is designed to receive or shall receive four hundred forty (440) gallons per day or less per forty thousand square feet (40,000 sq. ft.) of lot area.
- On-site subsurface sewage disposal systems for single-family dwellings shall be designed for the actual number of bedrooms present or by that number determined by the Board of Health or its Agent. On-site subsurface sewage disposal systems designed for less than 3 bedrooms shall cause a deed restriction to be placed on the property limiting the number of bedrooms to those present.
- The creation of a subdivision or Open Space Residential Development (OSRD) of three (3) or more lots shall be serviced by a shared or common on-site subsurface sewage disposal system that provides nitrogen removal technology.
- A division of land, involving existing dwelling units, resulting in the creation of parcels which are not in compliance with Section 5.1 of this regulation shall cause each parcel to install an on-site subsurface sewage disposal system that provides nitrogen removal technology. Each parcel affected by this section may be allowed one additional bedroom upon approval by the Board of Health.
- For residential applications the Board may allow, by variance, one (1) additional bedroom over the number allowed by Sections 5.1 or 5.2 with the use of an innovative/Alternative Technology on-site subsurface sewage disposal system.

Rules and Regulations of the Sewer Department - In 2005 Chatham Town Meeting adopted a new Article to the *Town of Chatham Rules and Regulations of the Sewer Department* which were initially adopted in 1972 and revised in 2004. The new Article II, *Regulation of Sewer Flow*, was adopted in response to concerns that future sewering could lead to increased development. The basic premise of the regulation is to limit sewage flow from a property to that allowed under Title 5 and Local Board of Health Regulation, which ever is lower (i.e. so-called "flow neutral"). Key provisions of the regulation include:

- Existing Structures - "Any structure in existence on May 10, 2005 regardless of its flow, may maintain that flow. No person shall modify an existing structure or change its use so as to increase its sewage flow…."
- Determination of Present Sewage Flow - "Sewage flow to the municipal sewer shall be determined using provisions set forth in 310 CMR 15.203: Sewage Flow Design Criteria, and any local board of Health Regulation modifying such in effect on May 10, 2005." (see: http://www.mass.gov/dep/service/regulations/310cmr15.pdf)

- Undeveloped Parcels – "For the purpose of determining sewage flow, any existing lot, otherwise qualified, may be permitted for that sewage flow as determined under the Board of Health's Regulations in affect on May 10, 2005 or 310 CMR 15.00 et seq, whichever is less."
- Rebuilding – "A property owner may rebuild a structure destroyed by fire, flood, storm or other acts of nature as a matter of right provided that the new structure does not exceed the sewage flow of the structure being replaced."
- Variances – there is a variance provision allowing sewage flow beyond that discussed above following a public hearing process.

Wetlands Protection - In 2004 the Chatham Wetlands Protection Bylaw was amended to include the Adjacent Upland Resource Area (AURA) (i.e. the so-called buffer zone) as a resource area to be protected and defined a No-Disturb Zone. The No-Disturb Zone is defined as the first fifty (50) feet of the AURA in which "…no substantial activity (other than maintenance of an already existing structure), which will result in the building within or upon, filling, removing, or altering of land, shall be permitted by the Commission, except for that which is allowed under a conservation variance". Regulations subsequently adopted by the Commission for the AURA speak clearly to the importance of vegetated buffer strips in addressing nutrient runoff. In addition, the 2004 amendments expanded the area of jurisdiction under the Bylaw to include "Within the boundaries of any area of critical environmental concern".

The full text of the Bylaw and regulations are available at the Chatham Conservation Division website: http://www.chatham-ma.gov/Public_Documents/ChathamMA_Health/conservation

5.2.5.3 Planning

Wastewater Management Planning - Chatham began its Comprehensive Wastewater Management Planning in 1997 with the formation of a Citizens Advisory Committee (CAC) to work with town staff (Technical Advisory Group, TAG) and the Town's consultants. Chatham's town-wide DRAFT CWMP/DRAFT Environmental Impact Report (EIR) was completed in April of 2008 and was submitted to the Commonwealth's MEPA unit and Cape Cod Commission (CCC) for approval. The town received the Secretary of Energy and Environmental Affairs Certificate in June 2008 with a determination that the Draft "adequately and properly complies" with the MA Environmental Policy Act. The town is currently in the process of responding to comments made on the Draft CWMP/Draft EIR during the MEPA review. The town expects to file a FINAL CWMP/FINAL EIR with MEPA and the CCC in late 2008 or early 2009.

In addition, the Town has completed preliminary design of an upgraded, expanded wastewater treatment facility (WWTF) and a town-wide sewering master plan in accordance with the recommendations of the DRAFT CWMP. The Town has secured funding for next step of final design of the new WWTF from local appropriation and the USDA Rural Utilities Program. The town expects to begin final design in 2009. The Town has also submitted a 2009 Project Evaluation Form as the initial step in obtaining project funding from the State Revolving Fund.

The full text of the CWMP is available at: http://www.chatham-ma.gov/public_documents/ChathamMa_CWMPlan/CWMP.

5.2.5.4 Capital Improvement Planning

Section 6-2, Capital Improvements Program, of the Town of Chatham Charter states: "The town manager shall submit a five-year capital improvement program to the board of selectmen at the date fixed by bylaw for the submission of the proposed operating budget unless some other time is provided by bylaw."

5.2.5.5 Local Comprehensive Plan

The Town of Chatham Comprehensive Plan, adopted by town meeting in 2003, contains a number of provisions relative to nutrient management. A significant number of the recommendations had been implemented or are in process. Examples include, but are not limited to:

- Density limits (dwelling units per acre) should be established consistent with the character of each Neighborhood Center. A limit on commercial density/intensity should also be set. (LU2)
- Allow Open Space Residential development in all zoning districts with minimum lot sizes appropriate to each district. Require residential subdivisions to submit Open Space Residential as an alternative to a standard subdivision. (LU 15)
- The Town should establish and fund a program to acquire property to create and maintain open space. Private entities also should acquire property to preserve it as open space. (LU16)
- Institute a phased program for the construction of public restrooms which are environmentally friendly. (CF8)
- Develop a wastewater sustainability goal for 2020. (CF25)
- Complete the town-wide Wastewater Management Plan by the end of 2005. (CF26, NR1)
- Implement the recommendations of Wastewater Management Plan and establish a mechanism for ensuring that recommendations of the Plan are moved forward through the regulatory and financing process with public and private cooperation. (CF27)
- Continue the policy of upgrading catch basins on town roadways during repaving and reconstruction projects I order to reduce stormwater pollutants reaching the towns ponds, streams, and groundwater. (CF30)
- Designate nitrogen sensitive areas as appropriate, through the processes outlined in state environmental and Chatham Board of Health regulations. (NR2)
- Support research, evaluation, and approval of alternative septic system technology aimed at nutrient reduction (nitrogen and phosphorus), especially on systems appropriate for seasonal use. (NR3)
- Reduce the nitrogen load to impacted embayments or freshwater bodies through the purchase of, or seek donation of land. (NR4)
- Educate the public to the benefits of, and encourage the use of, native, low maintenance landscaping to minimize the use of fertilizers. (NR5)
- Continue the town's Coastal Water Nutrient monitoring Program and freshwater pond monitoring programs to ensure the availability of sound scientific data upon which to evaluate the condition of Chatham's waters and to guide management decisions. (NR9)

The complete Comprehensive Plan is available at: http://www.chatham-ma.gov/Public_documents/chathamma_planning/CLRPTOC.

5.2.6 Town of Harwich

5.2.6.1 Regulations

Board of Health Regulation - As an interim measure prior to the development and implementation of a Comprehensive Wastewater (nitrogen) Management Plan (CWMP) for Pleasant Bay, any development of a subdivision, re-subdivision, or ANR creating five lots or more that is located in whole or in part within the watershed of Pleasant Bay as defined in said (TMDL) report shall be served by a shared septic system that provides nitrogen removal technology. Removal limits shall be those approved by MassDEP for the technology proposed. The system may be located anywhere within the subdivision, including on open space, if any, subject to all applicable rules, regulations and laws (Approved 3/15/2007).

5.2.6.2 Planning

Wastewater Management Planning - Harwich established a Water Quality Task Force in September 2007 to initiate development of a CWMP (http://www.hwqtf.com/CWMP%20Minutes.htm)

5.2.7 Town of Orleans

5.2.7.1 Zoning

Wetlands Bylaw - The Orleans Conservation Commission has designated three setback zones within the 100 foot wetlands buffer (0-25 feet, 25-50 feet, and 50-100 feet), each with more stringent requirements for the protection of the wetland resource. This bylaw states that: "Wetlands within the Pleasant Bay ACEC watershed and its embayment's are protected by a provision that defines nutrient control as a high priority and a "no adverse impact." This standard also affects the regulation of septic systems and other nutrient sources under their jurisdiction.

5.2.7.2 Regulations

Board of Health Regulations - Specific areas of Orleans are designated as Nitrogen Sensitive Areas where limits are placed on the flow of wastewater, depending on the use of the structure. These include: residential buildings can have no more than 110 gallons/bedroom or no more than 440 gallons per acre; existing commercial development with a total Title 5 sewage flow of under 10,000 gallons per day can expand or change the use as long as the sewage flow remains less than 10,000 gallons per day; subdivisions creating three (3) or more parcels, regardless of existing dwelling units; construction of multi-family and single family dwellings; alterations, additions or changes in use to existing dwellings that would increase the calculated sewage design flow. As defined in this provision, a dwelling on a 10,000 square foot parcel lot is not allowed to have more than one bedroom or a flow that exceeds 110 gallons/day and a dwelling on a 40,000 sq.ft lot, not more than four bedrooms (Adopted 5/1/2008).

Site Plan Review - The Site Plan Review Committee reviews and approves all Special Permit Applications that appear before the Zoning Board of Appeals (ZBA) before the ZBA makes its final ruling. Because the Conservation Commission is a member of this Committee, the wastewater management strategies that have the potential of affecting sensitive natural receptors, such as Pleasant Bay, will be considered prior to the ZBA's approval.

5.2.7.3 Wastewater Management Planning

Wastewater Management Steering Committee - In 2000, the Orleans Board of Selectmen appointed members to the newly formed Wastewater Management Steering Committee with representation from the Planning Board, Conservation Commission, and Board of Water Commissioners. See: http://www.town.orleans.ma.us/Pages/OrleansMA_BComm/wastewater

CWMP Citizens Advisory Committee - The draft comprehensive wastewater management plan that was completed in 2008 was successfully submitted for ratification by Town Meeting on October 27, 2008. This approval sets the stage to finalize the draft for submission to MEPA and ultimately to MassDEP for its approval to sewer 52 percent of the town and to construct a new sewage treatment plant and septic waste treatment facility at the existing Tri-town plant site off Route 6A.

The Draft CWMP is available at: http://www.town.orleans.ma.us/Pages/OrleansMA_BComm/cwmp and its Executive Summary:
http://orleansma.virtualtownhall.net/Pages/OrleansMA_BComm/docs/cwmp0908/summary.pdf

Town of Orleans's Wastewater Outreach/Public Education website:
http://www.town.orleans.ma.us/Pages/OrleansMA_BComm/wastefaqs

5.3 Regional Accomplishments: Barnstable County

At the county level, the Barnstable County Assembly of Delegates and the Cape Cod Commission have been leaders in recognizing the economic and environmental health implications of nitrogen pollution to the Cape's coastal estuaries; seeking regional and local solutions to address the reductions needed.

5.3.1 Cape Cod Commission's Regional Policy Plan: No-Net Nitrogen

Since its implementation, the no-net-nitrogen (NNN) policy has been applied to about ten developments in Mashpee (not all in the Popponesset Bay watershed). The usual approach is to require a higher level of nitrogen treatment, either through a small treatment plant for commercial projects or onsite denitrifying systems for residential development. An additional offset method commonly applied is funding for open space land purchases or contributions to an escrow account, which will be used in future efforts to reduce nitrogen pollution. Mashpee currently holds over $300,000 in escrow for this purpose.

Mashpee Commons: As a DRI the Mashpee Commons project was required by the Cape Cod Commission to comply with its "No Net Nitrogen increase" policy to offset each increment in nitrogen loading from its project through a reduction elsewhere within the Popponesset Watershed. This requirement was the basis for the expansion of the Mashpee Commons treatment plant to provide that offset capacity. While this privately owned wastewater treatment plant has the capacity of hooking up privately owned properties to offset its increase in nitrogen loading, the Town of Mashpee is the only entity with the legal authority to require area homes to hook up. Therefore, to accomplish this offset the municipality needs to establish a relationship with the Commons to require these connections. The legal implications have yet to be defined.

5.3.2 Cape Cod Commission's 2008 Draft Regional Policy Plan

The full text of the2008 Draft Regional Policy Plan is available on the Internet at: http://www.capecodcommission.org/RPP2008/RPP2008REVISED-103008.pdf. Pertinent components of the RPP that pertain to the role of the Cape Cod Commission in the MEP and the support provided to the Cape's communities regarding wastewater management planning is provided below.

Water Resources Goal – WR3: Marine Water Embayments and Estuaries: To preserve and restore the ecological integrity of marine water embayments and estuaries.

> "Cape Cod has at least 59 estuary systems that have the potential to be significantly impacted by excessive nitrogen loads from development in their watersheds. Excessive nitrogen leads to fundamental changes in these coastal ecosystems. Deterioration can affect the use and aesthetics of these resources and potentially lower property values. On-site septic systems are the primary source of nitrogen in most estuary watersheds, generally accounting for at least 75 percent of the nitrogen load.
>
> To address these concerns, the Cape Cod Commission and Barnstable County have been partners for the last six years in the Massachusetts Estuaries Project (MEP). The county has provided more than $600,000 of funding to the project; these funds have allowed the Commission to provide technical expertise toward the development of watershed nitrogen-loading models. The MEP, which is led by the School of Marine Science and Technology (SMAST) at the University of Massachusetts–Dartmouth, assesses the health of each embayment/estuary system and determines an appropriate nitrogen limit or threshold for each individual estuary. The thresholds, officially known as Total Maximum Daily Loads or TMDLs, are adopted by the Massachusetts Department of Environmental Protection and the US Environmental Protection Agency and are enforceable

under the federal Clean Water Act. Town Comprehensive Wastewater Management Plans and local, regional, and state regulations are being developed to meet these limits. Incorporating the TMDLs into regional and local regulations and supporting management solutions will help restore and protect coastal embayments by reducing nitrogen loading from existing and proposed land uses."

Cape Cod Commission Actions**:**
WR3-C1. Regional Participation in the MEP: The Cape Cod Commission will continue to participate as a technical partner in the Massachusetts Estuaries Project by providing nitrogen-loading thresholds. The Commission will assist in the maintenance of the linked watershed/estuary models developed through the MEP and assist with the completion of model scenario runs for wastewater planning and evaluation of wastewater alternatives for specific embayments.

WR3-C2. Technical Assistance about Embayments and Estuaries: The Cape Cod Commission will continue to assist the towns, region, and state in the development and implementation of appropriate management solutions for protecting, remediating, and monitoring nitrogen-sensitive embayments and estuaries.

WR3.2 Maintain or Improve Nitrogen Loading In watersheds to estuaries/embayments where there are documented marine water quality problems and a critical nitrogen load has not been developed, including, but not limited to, those embayments shown on the Cape Cod Water Resources Classification Map, development and redevelopment shall maintain or improve existing levels of nitrogen loading, except as provided in WR3.3 and WR3.1.

WR3.3 Local Management Plans. In watersheds with Commission-approved watershed nutrient management plans, or comprehensive wastewater management plans, nitrogen loading from development and redevelopment shall attain the nitrogen loading limit specified by the plan.

WR3.4 Nitrogen Offset Contribution In watersheds to estuaries/embayments where development and redevelopment must meet either WR3.1 or WR3.2, development and redevelopment may meet these standards by providing an equivalent nitrogen offset contribution to be used toward meeting the intent of WR3.1 or WR3.2. The load requirements of WR3.1 and WR3.2 above may be achieved by providing wastewater treatment for the development or redevelopment and additional treatment capacity for nearby land uses, installation of alternative denitrifying technologies for existing septic systems in the same Marine Water Recharge Area, and/or an equivalent contribution of $1,550 per kg/yr of nitrogen towards a municipal or watershed effort that achieves the intent of WR3.1 and WR3.2.

WR3.5 Monetary Contribution. In watersheds where the critical nitrogen load has not been determined, development and redevelopment may be required to make a monetary contribution toward the development or implementation of appropriate nitrogen management strategies not to exceed $20 per gallon of design flow of wastewater per day.

WR3.1 Critical Nitrogen Load Standard for Development. In watersheds to estuaries/embayments where a critical nitrogen load has been determined, through either a Total Maximum Daily Load (TMDL), or a Massachusetts Estuaries Project-accepted technical report, development and redevelopment shall not exceed the identified critical nitrogen loading standard for impact on marine ecosystems, except as provided in WR3.3. The Commission shall maintain a list and map of estuary/embayment critical nitrogen loading standards; the list and map will be updated on a regular basis as TMDLs are approved by the Massachusetts Department of Environmental Protection and the US Environmental Protection Agency.

Recommended Town Actions:
WR3-T1. Local Participation in the MEP: The towns should continue to participate in the Massachusetts Estuaries Project, obtain Total Maximum Daily Loads for their coastal embayments and estuaries, and work to develop and implement solutions to meet TMDLs.

WR3-T2. Regional Solutions for Shared Watersheds: The towns should consider regional solutions for shared watersheds to marine embayments, such as planning, infrastructure, and management.

5.3.3 Cape Cod Commission Wastewater Planning Conferences and Publications

Conference: Restoring and Protecting Coastal Waters, November 16, 2006 (http://www.capecodcommission.org/water/conference/home.htm)

Publication: Enhancing Wastewater Management on Cape Cod: Planning, Administrative, and Legal Tools . Released July 2004 (http://www.capecodcommission.org/water/WastewaterToolsReport/WWToolsRept.pdf)

Publication: Cape Cod Comprehensive Regional Wastewater Management Strategy Development Project_ Final Report: June 2003.
http://www.capecodcommission.org/water/CapeCodRegionalWastewater.pdf

5.3.4 Cape Cod Water Protection Collaborative

The 2008 Environmental Bond Bill

This legislation was spear headed by the Cape Cod Water Protection Collaborative, submitted by Senator Robert O'Leary and approved by Governor Deval Patrick in August 2008 - the same year it was presented to the General Court (Appendix X). This legislation was attached as sections 5 and 10 within the Environmental Bond Bill (http://www.mass.gov/legis/laws/seslaw08/sl080312.htm) that now provides zero interest State Revolving Loan funding to municipalities that have completed the CWMP process with a MassDEP approved Comprehensive Wastewater Management Plan. Funding under this program expires in ten years.

CapeKeepers - CapeKeepers promotes public education on wastewater issues
http://www.capekeepers.org/cape-keepers/posters-and-audio

FY08 Grant Programs - Grant funding supports municipal efforts to address multi-town water quality issues. While allocated through the Barnstable County budget, the primary source of revenue to fund these projects was from the Registry of Deeds (see: http://www.capekeepers.org/cape-cod-water-protection-collaborative/grants--funding)

- Grant 1 - $75,000 to enhance local planning efforts, especially those focused on cross municipal borders. The grant would award 3-5 grants ranging from $25,000 to $50,000. Funded projects must be able to demonstrate the involvement and support of an adjoining community even if that community is not participating in the funding of the project.
- Grant 2 -$95,000 to support completion of MEP alternative model runs where more than one community is involved.

- $34,275 to the Town of Falmouth to work with Mashpee to evaluate wastewater disposal sites to accept wastewater disposal sites to accept wastewater removed from the Waquoit Bay watershed (see: http://www.barnstablecounty.org/documents/Falmouth-MashpeeWaquoitBayApplication.pdf).
- $48,900 awarded to the Town of Orleans Economies of Scale Proposal to quantify the potential cost savings associated with regional wastewater treatment and disposal facilities (see: http://www.barnstablecounty.org/documents/Application2--EconomiesofScale.pdf).
- $40,000 awarded to the Pleasant Bay Alliance to develop a fertilizer management strategy (see: http://www.barnstablecounty.org/documents/Fertilizermgntproposal.pdf)
- $35,000 awarded to the Pleasant Bay Alliance to study restoration of the Muddy Creek as a freshwater system that will remove nitrogen before it impacts the Bay (see: http://www.barnstablecounty.org/documents/Muddycreekproposal.pdf).
- "Eutrophication and You: The Future of Cape Cod" – A public outreach document describing the effects of nitrogen enrichment on Cape Cod waters.
- (7/24/07) "Request for Proposals from Consultants to Assist Barnstable County Water Protection Collaborative in Identifying Growth Impacts Resulting From Sewering and Creating Smart Growth Tools to Proactively Manage these Growth Impacts".
- RFP for the Regional Wastewater Plan. Members of the board worked with Senator Robert O'Leary and his Legislative Aide, Nate Mayo, on the RFP for Barnstable County Wastewater Management Plan Development.
  - Phase 1: Synopsis of problem, including a public relations strategy.
  - Phase 2: Distribute to decision makers and a plan on how it will be distributed.
  - Phase 3: Technical proposal that integrates 15 local plans.

5.3.5 Coastal Zone Management National Estuarine Programs

As described in Section 1.4.2.5 each National Estuarine Program (NEP) is required under Section 320 of the federal Clean Water Act (http://www.epa.gov/owow/estuaries/320.htm) to prepare a Comprehensive Conservation and Management Plan (CCMP) (http://www.epa.gov/owow/estuaries/ccmp/index.htm) to control point and nonpoint sources of pollution to supplement existing controls of pollution and is developed and approved by a broad-based coalition of stakeholders. Currently, two CCMPs guide the two NEP programs in Massachusetts:

- Buzzards Bay (http://www.buzzardsbay.org/ccmptoc.htm)
- Massachusetts Bay (http://www.mass.gov/envir/massbays/ccmp.htm)

Each CCMP serves as a blueprint for coordinated action to guide future decisions and actions that address a wide range of environmental protection issues including water quality, habitat, fish and wildlife, pathogens, land use, and introduced species to name a few. To carry out its objective, these CCMP feature action plans with specific recommendations for pollution prevention, habitat preservation, and the restoration of the Bays degraded resources that would be carried out by dozens of organizations, both governmental and non-governmental, each responsible for taking the steps needed to protect and restore the Bays.

A CZM funded project worthy of note:

- Model Stormwater Management Bylaw (http://www.horsleywitten.com/pubs/MSM-bylaw-regs.pdf)

5.4 Massachusetts DEP Accomplishments

5.4.1 Inter-Municipal Wastewater Management Planning

The Assabet River Consortium - When the NPDES permits to four treatment plants on the Assabet River were due for renewal, the MassDEP required each of the communities served by the plants to study regional wastewater treatment issues. As a result, the six communities entered into an inter-municipal agreement that legally bound them to prepare and cover the cost of a jointly prepared CWMP; including additional inter-municipal agreements to finance and carryout its requirements to restore water quality to the Assabet River from a variety of nonpoint sources in the Assabet River Watershed and the point discharges from the four wastewater treatment facilities serving the six towns: Hudson, Marlborough, Maynard, Northborough, Shrewsbury, and Westborough. The consortium brought them together to leverage their resources and share information and expertise as they worked on a watershed-based plan to meet the anticipated future needs of each community for the protection of the Assabet River. It was estimated that 80 percent of the river's flow during extreme summer lows were comprised of treated wastewater from the four facilities. The CWMP prepared by the Consortium to upgrade the four treatment plants evaluated the cost-effectiveness, environmental impact, and ability to achieve ground and surface water quality standards. The preparation of the CWMP required that it undergo four phases, prior to its submittal to the Environmental Protection Agency and MassDEP.

The EPA/MassDEP NPDES permit that was drafted in June 2004 represented an 87% phosphate load reduction from the four major wastewater treatment plants during April 1 - October 31 (the vegetative growing season of river weeds nourished by phosphorus). While consortium communities maintain their independence, this collaborative, regional, watershed-based approach has expanded the universe of possibilities for each community's wastewater treatment plans. For more on the Assabet Consortium go to: http://www.epa.gov/ncei/stategrants/PDFs/AssabetRiverWorkplanpdf.pdf and http://www.epa.gov/ncei/stategrants/PDFs/MAUpdate.pdf

5.4.2 Nitrogen Trading

5.4.2.1 Wayland Business Center. This office building complex sought to discharge effluents from its wastewater treatment plant into the Sudbury River. The facility had been operated by the Raytheon Corporation, and the new owners originally sought to renew and transfer the existing permit. The Massachusetts Department of Environmental Protection and the U.S. EPA ruled that the Raytheon permit could not be transferred to the new owners of the Wayland Business Center, and hence the facility's discharge was to be construed as a new discharge.

As a condition for allowing the discharge, the NPDES permit specified that the Raytheon facility needed to obtain an offsetting reduction in phosphorus. The facility is obtaining offsets by connecting neighboring properties to the plant. Approximately 33 septic systems that are in a high water table area and/or are failing will be connected to the private sewer system.

5.4.2.2 Edgartown. The wastewater treatment facility (WWTF) was upgraded in 1996 to meet Class I Ground Water Discharge Standards, with a goal of limiting the annual nitrogen loading to 2200 kilograms (see: http://www.mass.gov/dep/service/regulations/314cmr05.pdf). Although the facility is designed for 750,000 gallons per day (gpd), the groundwater discharge permit limits the flow initially to 500,000 gpd until actual performance data is available. To date, the facility has exceeded expectations with an average total nitrogen discharge below 5 mg/L. Approximately 300 additional residences in the recharge area will be connected to the facility, but there is no current timetable for this phase of the project. Dentrifying on-site treatment systems will be encouraged elsewhere within the watershed.

5.4.2.3 Falmouth. The WWTF is being upgraded from a Class III to a Class I ground water discharge (see: http://www.mass.gov/dep/service/regulations/314cmr05.pdf). Construction of the new facility is expected to begin in the Spring of 2003. More than 400 additional connections will be made to the treatment plant from homes and businesses in the watershed west of Route 28. There is no current timetable for this phase of the project. Dentrifying on-site treatment systems will be installed at sites east of Route 28, and will be centrally managed. A management plan still needs to be implemented to oversee this work.

The treatment plant will be designed at 1.2 MGD to meet a 3 mg/L total nitrogen discharge at a maximum rate of 1 MGD within the watershed. Any additional discharge will have to occur outside the watershed.

5.4.3 Natural Attenuation of Nitrogen in Wetlands and Surface Waters

In response to the use of natural attenuation as an alternative to wastewater treatment, MassDEP initiated the scientific and regulatory work to govern this strategy. Massachusetts has some of the most protective wetland regulations (see: http://www.mass.gov/dep/service/regulations/310cmr10a.pdf and http://www.mass.gov/dep/service/regulations/310cmr10b.pdf.) in the U.S to implement the Wetlands Protection Act (WPA) (http://www.mass.gov/legis/laws/mgl/131-40.htm).

The Wetlands Protection Act does have room for projects that impact a wetland resource but they must provide for overall resource enhancement. Existing examples include the installation of fish ladders for the migration of anadromous fish and the management of invasive species within its impacted lakes and ponds. MassDEP's Guidance for Aquatic Plant Management in Lakes and Ponds describes the Department's approach to resource enhancements (see: http://www.mass.gov/dep/water/laws/alkguide.pdf).

Extending this approach to projects that enhance natural attenuation of nitrogen will require balancing the various interests of the WPA. For example, alterations could negatively impact a freshwater wetland (e.g., destruction of bordering wetlands vegetation) in order to improve water quality downstream to the estuary.

Key elements of the Guidance are already clear:

1. Enhanced natural attenuation cannot be the only method used for attenuating nitrogen in a watershed, but must be considered in conjunction with another strategy that includes wastewater treatment, stormwater and fertilizer controls, and water conservation. Enhanced natural attenuation may be useful in combination with other attenuation alternatives such as wastewater treatment and stormwater management.
2. Alterations in different resource types will raise different issues with the WPA. The following list ranks protected resources in increasing order of concern:
   a. Creation of constructed wetlands raise the fewest concerns
   b. Wetlands systems which have already been altered, e.g., recently abandoned cranberry bogs
   c. Resources which have been altered, but are long-standing (e.g., long-abandoned cranberry bogs)
   d. Conversion of one type of resource to a different type
   e. Alteration of pristine, well-functioning wetlands would raise the most concerns. Salt marshes are of particular concern because of their limited scope and high ecological value. Although the

WPA does not have a resource enhancement exemption for coastal habitat, projects that enhance the salt marsh are allowed under 310 CMR 10.32 (5).

3. Alterations must demonstrate a positive impact on interests of the Act. Stronger cases for alteration will have the following characteristics:
    a. Larger number of interests supported (e.g., pollution prevention, fish habitat, preventing erosion and siltation)
    b. Documentation of negative impacts and efforts to minimize them
    c. Higher percentage of nitrogen attenuation
    d. Ability to predict and measure attenuation.

5.4.3.1 Natural Attenuation Literature Review

The first step in the use of Enhanced Natural Attenuation for the reduction of nitrogen loads was to fund a search of scientific literature, with funding from the EPA Cooperative Agreement. This search of the literature, mined by the contractor, the Woods Hole Group and its subcontractor, Teal Partners, provided the Department's policy and regulatory staff and the Massachusetts Estuaries Project (MEP) with the following:

- The current state of our knowledge concerning the attenuation/cleanup of nitrogen contaminated ground and storm water by both natural and constructed wetlands
- The effectiveness of natural wetland system processes for removing nitrogen contaminated groundwater by wetland ecosystems
- Optimal designs and site modifications of wetlands to enhance nitrogen removal by natural attenuation
- Reports on the benefits and detriments of nitrogen attenuation in wetland ecosystems
- MassDEP data needs for the review of natural attenuation project proposals

This was a first step in the policy development process for external and internal discussion concerning the effectiveness, limitations in use, and applicability under existing state statutes and regulations of nitrogen attenuation. The findings of this literature review will allow the MassDEP to consider the effectiveness of nitrogen attenuation as a treatment option to reduce impacts from nitrogen-contaminated groundwater that would otherwise contribute to estuarine eutrophication.

This literature search confirmed that natural attenuation, via bacterial denitrification, is an effective mechanism for the treatment of nitrogen-contaminated groundwater. Vegetative uptake was reported as having a minor role in nitrogen removal. The most important physical characteristics that promote nitrogen removal are the groundwater nitrate concentrations, the detention treatment time within the pond and/or wetland system, the anoxic zones, organic carbon, temperature and pH. Specifically, the conditions that were identified to maximize nitrogen removal include the following: a nitrate loading rate of ~ 2 to 3 mg/l, a detention time of about one day in anoxic zones with labile organic carbon, near neutral pH, and temperatures ~ 10° C. The role of climate (wind, rain, season, air and water temperature) was also explored. Finally, wetland modifications that may enhance nitrogen removal from ground and surface waters in Massachusetts are described.

5.4.3.2 Literature Review Key Findings

The state of the literature and research on natural bogs and fens was determined as not sufficient for use in promoting techniques to use these wetlands as natural nitrogen attenuators without endangering either the resource itself or the downstream resources. The investigators reported that the data required was currently insufficient to making modifications to natural bogs and fens; recommending that natural bogs not be used for natural attenuation projects at this time.

For all other water bodies and wetlands (streams, rivers, lakes and ponds; wet meadows/ freshwater emergent/constructed wetlands; cranberry bogs; woody and open wetlands/riparian zones; salt marshes, ponds and mud flats), the study reported the following data needs prior to reviewing and permitting natural attenuation projects.

- Nitrate Concentration: Measure *in situ* nitrogen up and down gradient to confirm that the proposed site is not already over burdened with N. If the site is acceptable, measure nitrate concentration in ground or surface water proposed for diversion into the site. Try to determine the source of nitrate and estimate whether it is consistent, seasonal or event driven. Higher influent nitrate concentrations are preferred because the microbial biomass thrives at higher concentrations, leading to better denitrification rates. In addition, from a cost/benefit perspective, the outcome (impact on the receiving water) is likely to be measurable if you choose to treat higher concentrations. If nitrate concentrations are below 3 mgl^{-1}, longer detention times are needed. Moreover, if ground and/or surface flows to the wetland or waterbody have periods with no nitrate, then several hours additional detention time at ~10°C is necessary to reactivate denitrification.
- pH: near neutral is best -- 6.5 to 7.5 units
- Anoxic conditions: required. This can be measured with a redox electrode.
- Temperature: best denitrification occurs when water temperature is 10°C or above. Some denitrification occurs at temperatures > 4°C.
- Detention time in sediment is estimated from soil samples and dependent on its permeability. A minimum of 12 hours detention time in the anoxic zone of the wetland is required. A detention time of two to three days is preferred in lakes and ponds (Fleischer et al. 1994, Ahlgren et al. 1994).
- Labile organics: The nature of the substrate, the detention time in the anoxic substrate and the labile organic content affect the rate of denitrification. The labile organic content can be estimated as chemical oxygen demand (COD), which needs to be more than four times the concentration of the nitrate to be denitrified. Of course, this must be continuously replenished from local sources (decomposition or release from living organisms) for denitrification to continue. For example, sediment with over 15% organic content will probably suffice as will active growth of emergent and submerged herbaceous marsh plants.

See Appendix J for the Executive Summary of this report or download one or more of the project deliverables listed under "Natural Attenuation of Nitrogen in Wetlands and Waterbodies" at http://www.mass.gov/dep/water/resources/coastalr.htm

- Final Report: Natural Attenuation of Nitrogen in Wetlands and Waterbodies,
- Literature Review, Bibliography with Abstracts and Annotations
- Natural attenuation (literature findings as Excel spreadsheet

Chapter 6: Regulations, Policies, and Guidance: Stakeholder Recommendations for Future Planning

The recommendations presented in this chapter reflect the views of the stakeholders throughout Cape Cod – those who have been actively engaged in watershed-based TMDL planning and implementation. They include members of the Popponesset Bay, Three Bays, and the Pleasant Bay Pilot Projects and those representing a working group of the Barnstable County Wastewater Implementation Committee (WIC), as reported to the Cape Cod Commission by it contractor Wright-Pierce (2004) (http://www.capecodcommission.org/water/WastewaterToolsReport/WWToolsRept-Chapt10.pdf). On Cape Cod, the nitrogen loads that affect embayment water quality are primarily from unregulated on-site wastewater treatment and discharges, and secondarily from stormwater runoff and fertilizer use. Unlike end of pipe NPDES point source discharges, nonpoint source discharges are dispersed throughout a watershed and not easily removed.

Nitrogen reduction is best achieved when the loads from each community within a watershed have been defined, as they have been for several coastal watersheds on Cape Cod by the MEP Technical Reports. With this information and several MEP scenario model runs, it is possible to identify what location(s) within a watershed will achieve quantifiable reductions at an optimal cost and environmental benefit.

The stakeholders whose thoughts are presented below have been addressing watershed-based TMDLs and have become knowledgeable of the MEP approach for defining nitrogen loads and its impact on coastal estuaries but are equally experienced and knowledgeable of the challenges in developing and implementing a CWMP. The stakeholder recommendations are grouped as follows:

- Inter-municipal TMDL planning and implementation
- State Revolving Loan Funding
- State Permitting
- Environmental Planning Requirements
- Wastewater Management Planning and Reporting Requirements

The views presented below will be undergoing evaluation by MassDEP to address the issues that have been identified and will serve as a blueprint for prioritizing and taking action in the future. MassDEP does not necessarily agree with all the recommendations nor is MassDEP committing at this time to implement any of the recommendations.

6.1 Inter-Municipal TMDL Planning and Implementation

It is important that all towns within a watershed that contribute to a water quality problem become engaged in helping to implement appropriate solutions. Many times this has not been the case. Towns at the headwaters of a coastal watershed without frontage to the estuary may not be engaged because they may not understand how their proximity to the estuary affects water quality degradation. More outreach is needed to educate the public and to engage all communities in the watershed with this understanding.

6.1.1 Existing Capacity

- MassDEP staff support is available, on a limited consulting basis, to municipalities with willing community partners that have an interest in watershed-based TMDL planning and implementation.

- MassDEP can resolve regulatory and policy barriers as they arise, e.g. nitrogen contributions to an estuary by the towns sharing the watershed.

6.1.2 Defining Future Needs

- MassDEP should allocate town-by-town nitrogen reductions as an incentive for towns to do wastewater management planning (or to sign off on a towns' management proposal once the CWMPs are approved by the MassDEP).
- Towns not engaged in a CWMP should have their nitrogen reduction target assigned by MassDEP.
- MassDEP should be open to pilot projects and new methods for towns to demonstrate the impact of innovative approaches on nitrogen reduction (e.g. fertilizer reduction, stormwater treatment, enhanced natural attenuation, among others).
- Traditionally, MassDEP has limited its involvement to CWMP review/approval and permitting. Under the inter-municipal collaborative approach, the MassDEP should assist MEP communities, on an ongoing basis, with their planning and implementation decision making; which include:
    - Calculation of municipal nitrogen load contributions
    - Guidelines for inter-municipal collaboration
- Nitrogen contributions and allocations: Towns need nitrogen concentration as early as possible and some way to allocate the target kilograms.
- MEP Linked Model Peer Review. SMAST should publish the Linked Model in a referred ecological modeling journal to validate its applicability for the nitrogen reduction scenarios it prepares for use by towns. If not, MassDEP should pursue this review and decide how this could be accomplished, by whom, and with what funding.
- Clarification on the nature of approving CWMPs would be helpful; specifically regarding the level of detail that should be provided for a groundwater discharge permit to a town or district.
- Policy guidance is needed on whether TMDLs may be modified in light of changes to the Pleasant Bay inlet and barrier beach configuration. It also would be important to know if a town's CWMP can be approved without a model run scenario that showed concentrations being met throughout the system.
- To guide nitrogen reduction implementation activities in watersheds of impaired embayments, MassDEP should identify measures to balance nitrogen load increases from new development during the time period between EPA approval of the TMDL to completion of the CWMP.
- To require or encourage the multiple towns sharing a coastal watershed to coordinate their planning, additional MEP Linked Model runs should provide the nitrogen reductions that must be achieved at the time of submission of their proposals for a CWMP.
- In view of the MEP model run results, the towns within the same watershed should coordinate and identify the best option for reducing nitrogen loads within their town borders that is both environmentally and cost effective. The CWMPs that the MassDEP approves should identify how those watershed load reductions are allocated among the towns to achieve the threshold concentration in the watershed they share.
- MassDEP should provide guidance on long-term habitat and water quality compliance monitoring protocols for use by towns during CWMP implementation.
- Early in the MEP process (before the TMDL is submitted by the MassDEP for EPA approval), MassDEP should provide workshops to educate municipal decision-makers about the environmental impacts of nitrogen and wastewater management planning and implementation.
- Water Quality Offsets and Trading. Towns engaged in watershed-based collaborative problem solving should consider trading as a tool to defray CWMP implementation costs and to identify the most cost effective remedies. As a result, towns furthest from the shoreline could contribute to the cost of sewering locations closer to the shoreline where the nitrogen reductions have the greatest impact. However, water quality trading should begin only after the towns agree on the amount of nitrogen each town is responsible for reducing. Trading could engage the services of an outside party to monitor process and results. This could be a regional agency or MassDEP.

6.1.3 Considerations

- Massachusetts TMDL development and implementation have focused on watersheds with NPDES (point source) permits.
- MEP coastal watersheds are affected primarily from nonpoint source discharges. Mitigation of these nitrogen loads frequently require reductions by more than one community through TMDL related CWMP planning and implementation.
- TMDL planning and implementation is addressed through town specific, state regulated groundwater discharge permits. Watershed-based, multi-town permits have not been pursued.
- Other States, Oregon, California, and North Carolina, establish a state role in developing and carrying out implementation plans.

6.1.4 Key Elements of a Watershed-Based Wastewater Management Plan

- Local or regional obstacles to implement a watershed-based TMDL:
    - All towns sharing a nitrogen-sensitive embayment must coordinate efforts and all have some level of responsibility to restore the embayment habitat.
    - Funding of implementation projects, including the cost of sewers, is dependent on community-based outreach and planning. If the towns cannot convince its residents that implementation is needed then funding will not be provided. Elected officials must be educated to support sewering projects and other nutrient treatment programs (NDA, stormwater/road work, etc.). A Citizen Advisory Committee (CAC) can be the bridge between the town's technical staff and the community when proposing projects for funding.
    - Locating sites for wastewater treatment and effluent discharge.
- Watershed-wide, coordination and planning by communities sharing the watershed resource through a memorandum of understanding or other legal arrangement.
- Watershed-wide nitrogen reduction planning, via MEP scenario runs, for the identification of a plan that addresses the nitrogen threshold concentration in the estuary for TMDL compliance when implemented.
- Timeframe for actions and expected timeframe for CWMP development and TMDL implementation.
- Reasonable assurances and margins of safety: amplify what's in the TMDL.
- With the assistance of MassDEP, develop an acceptable plan that monitors the improvements in water quality following CWMP implementation of the capital improvements toward the TMDL and adaptive management.

6.2 State Revolving Loan Funding (SRF)

6.2.1 Existing Capacity

- Financing is available for town and watershed planning and implementation of many nitrogen-reducing alternatives. MassDEP reviews plans and can place conditions on their approval.

- As detailed in Appendix X and attached as sections 5 and 10 in the Environmental Bond Bill (http://www.mass.gov/legis/laws/seslaw08/sl080312.htm) that was approved by Governor Deval Patrick in August 2008, a category of projects was created for which 0% SRF financing is available. Proponents meeting the following requirements would be eligible for 0% CWSRF loans:
    - The project is primarily intended to remediate or prevent nutrient enrichment of a surface water body or a source of water supply;
    - The applicant is not currently subject, due a violation of a nutrient-related total maximum daily load standard or other nutrient based standard, to a department of environmental

protection enforcement order, administrative consent order or unilateral administrative order, enforcement action by the United States Environmental Protection Agency or subject to a state or federal court order relative to the proposed project;
  - The applicant has a Comprehensive Wastewater Management Plan approved pursuant to regulations adopted by the Department of Environmental Protection;
  - The project has been deemed consistent with the regional water resources management plans if one exists;
  - The applicant has adopted land use controls, subject to the review and approval of the department of environmental protection in consultation with the department of housing and economic development and, where applicable any regional land use regulatory entity, intended to limit wastewater flows to the amount authorized under zoning and wastewater regulations as of the date of the approval of the CWMP.

6.2.2 Defining Future Needs (includes MassDEP comment to these recommendations)

- MassDEP should investigate the feasibility of providing incentives to SRF applicants to promote intermunicipal collaboration for towns sharing a watershed resource. In many instances, intermunicipal TMDL planning and implementation can be the most cost and environmentally effective approach. (DEP cannot affect any SRF incentives. SRF Interest Rates are set by the Massachusetts Legislature)
- MassDEP should explore the benefits of requiring SRF recipients to complete the projects as specified in their CWMP. (The SRF program has no legal authority to require completion of projects in a CWMP. That 'completion' would have to result from enforcement by the waste water program, if necessitated by environmental or public health conditions. This bullet should not fall under the SRF heading, since MassDEP cannot obligate any community to borrow SRF funds to institute a project.)
- MassDEP should (continue to) ensure its SRF funding program supports MEP work, and should link towns and watershed organizations to other funding sources.
- While MassDEP in the past has "set aside" funds for certain categories of projects, MEP communities will have to compete with other projects statewide. However, the fact that the projects are based on TMDL reports and are regional based should help in receiving priority. (The O'Leary Bill (Appendix X) effectively did establish a set-aside for nutrient mitigation projects, so this bullet point is no longer relevant.)
- MassDEP should reconcile expending SRF funds with the delays in the MEP process. It is critical that towns know SRF funds will be available when they have all the other pieces in place to move forward. (SRF financing has been available to, and used by, MEP communities throughout the MEP "delay." This point is irrelevant.)
- MassDEP, thru its SRF, should assist towns with the financing to acquire private wastewater treatment facilities. (If it is the desire of any community to acquire private WWTF's, the acquisition is eligible.)
- Waste Water Districts should be considered as an efficient and cost saving management option for preparing and implementing a CWMP. The key question to resolve among the affected communities is the allocation of watershed nutrient loads and costs between communities.
- Escrow accounts. Rather than implementing enhanced treatment for individual homes prior to developing an area-wide CWMP solution, the cost of enhanced treatment should be placed in escrow and later used to offset a homeowner's share of implementing the overall wastewater management plan. (The 2008 Environmental Bond Bill (outside Sec.10) contained language allowing communities to elect to adopt this approach (see Appendix X).)
- Amend MGL C.83 §3 to allow "checkerboard" sewer systems without requiring individual communities to file special legislation. (The 2008 Environmental Bond Bill (outside Sec.10) (Appendix X) contained language allowing communities to elect to adopt this approach.)

6.3 State Permitting

6.3.1 Existing Capacity

- MassDEP's has the authority to permit existing groundwater and surface water discharges.
- MassDEP promotes a collaborative voluntary approach to CWMP planning in recognition that towns are the decision makers on CWMP implementation.

6.3.2 Defining Future Needs

- There is consensus that local decisions will not happen without knowledge of a potential state action if towns do not act. The MassDEP should set criteria for deciding when an enforcement action should be pursued when CWMP implementation is not making adequate progress.
- Codification of point of compliance – through the Working Group, the Pleasant Bay Alliance communities have learned about the policy direction under discussion by MassDEP regarding point of compliance. MassDEP's codification of this approach through a policy guidance or similar document has been requested.
- MassDEP should evaluate its authority to promote a voluntary approach for the mitigation of nonpoint sources discharges to TMDL listed waters.
- MassDEP should clarify its regulatory role, particularly regarding enforcement. Early successes with a voluntary approach will demonstrate value of this approach. Given its ultimate regulatory role, MassDEP is not a neutral party in planning and implementation. The MassDEP should acknowledge its position and work with towns and regional groups; using neutral parties as facilitators and mediators.
- Towns should collaborate with each other to identify cost-effective and effective solutions that best fit with local needs and resources. When Towns consider a range of specific solutions based on Town-specific concerns, taxpayers in the watershed should have access to a wide range of alternatives, including those that are most cost-effective for residents of the watershed as a whole.
- If the towns choose not to coordinate their planning, the MassDEP approval of a CWMP should be conditioned for the towns to demonstrate that they have identified the load reductions, via Linked MEP Modeling, that they are responsible for reducing on their own for restoring water quality in the embayment. This approach should encourage the towns to coordinate their planning for the load reduction throughout the coastal watershed.
- Monitoring protocol and reporting procedures – The Pleasant Bay Alliance has requested clarification on MassDEP's monitoring requirements, protocols and reporting procedures necessary to demonstrate TMDL compliance.
- MassDEP Wetlands Program should decide if credit should be given for projects that increase existing natural attenuation and should provide guidance to Conservation Commissions when these projects come for their review under the Wetlands Protection Act. These two efforts need to proceed in tandem.
- MassDEP should allow Towns to use different permitting approaches to achieve the required nitrogen reductions, so long as they meet MassDEP's standards of success. The MassDEP should formalize this approach through existing policies and regulations.
- Existing policy and regulatory tools are blunt, and not the best for towns to use.
- When two or more communities share a coastal watershed, the MassDEP should adopt a local/regional/state joint review of a town's proposed CWMP, prior to the MassDEP's approval.
- MassDEP should adopt interim measures for use in determining when a MassDEP approved CWMP is making adequate progress toward water quality improvement.

6.4 Environmental Planning Requirements

6.4.1 Existing Capacity

- Projects that trip certain development thresholds are required by the Massachusetts Environmental Policy Act and the Cape Cod Commission's Regional Policy Plan (RPP) to undergo a review processes when they are located in state designated nitrogen sensitive watersheds. Below are answers to some common questions on MEPA and RPP Developments of Regional Impact (DRI) (http://www.capecodcommission.org/regulatory/driQA.htm).
  - Projects that meet or exceed a MEPA Threshold. For example, direct alteration of 25 acres or more; a new Waste Water Treatment Facility for 100,000 gpd or more; expansion of an existing WWTF by 100,000 gpd or 10%; construction of one or more sewer mains. (see: http://www.mass.gov/envir/mepa/thirdlevelpages/thresholds.htm).
  - MEPA/DRI Interface: According to the CCC website, "Projects requiring review under the Massachusetts Environmental Policy Act (MEPA) may also require DRI review. An applicant may request a joint review process with the state and the Cape Cod Commission."
  - The process: "Whenever a developer files an Environmental Notification Form (ENF) with MEPA for a project in Barnstable County, it triggers a DRI application with the CCC.
    - The Commission, through a subcommittee, advises MEPA. The Commission and MEPA hold joint public hearings on the proposal and the subsequent Draft EIR.
    - MEP tells the developer what issues should be addressed. The applicant submits a final EIR. Another joint public hearing is held.
    - The commission and MEPA review that report. MEPA decides whether to issue a certificate allowing the developer to proceed.
    - If MEPA issues the certificate, the commission begins its DRI review process within 45 days.
  - When Cape Cod Commission DRI thresholds are met:
    - subdivisions of 30 acres or more
    - development of 30 or more residential lots or dwelling units
    - development of 10 or more business, office, or industrial lots
    - commercial development or change of use for buildings greater than 10,000 square feet
    - transportation facilities for passage to or from Barnstable County
    - demolition or major changes to some national- or state-recognized historic structures
    - bridge, ramp, or road construction providing access to several types of water bodies and wetlands
    - new construction or change of use involving outdoor commercial space greater than 40,000 square feet
    - construction of any wireless communication tower exceeding 35 feet in height
    - site alterations or site disturbance greater than two acres without a valid local permit
    - mixed use residential and non-residential developments with a floor area greater than 20,000 square feet
  - DRIs that are planned for locations within nitrogen sensitive watersheds with a nitrogen TMDL are governed by the Cape Cod Commission's RPP's No-Net Nitrogen provisions (http://www.capecodcommission.org/RPP/). In watersheds to coastal embayments, projects must conform to watershed-specific critical nitrogen loads. Where existing nitrogen loads exceed critical loads, or where there is demonstrated water quality impairment, the Plan requires no net nitrogen increase. As presented in the Draft RPP's Water Resources Section WR#.3.1: "In watersheds to estuaries/embayments where a critical nitrogen load has been determined, through either a Total Maximum Daily Load (TMDL), or a Massachusetts Estuaries Project-accepted technical report, development and redevelopment shall not exceed the identified critical nitrogen loading standard for impact on marine ecosystems, except as provided in WR3.3."

- MassDEP comments during the MEPA review.

6.4.2 Future Needs Defined

- MassDEP should integrate its inter-municipal, watershed-wide planning concepts when revising its CWMP guidelines.
- Cape Cod Commission Developments of Regional Impact (DRI) are less common as the larger parcels on the Cape have already been developed. DRIs require application of the County's No Net Nitrogen regulations, under which developers must offset increases in nitrogen flows. (see: http://www.capecodcommission.org/regulatory/driQA.htm)
- Towns should address the growth impacts to coastal watersheds from the controllable loads of nitrogen resulting from the installation of on-site wastewater treatment and disposal, fertilizer use, and stormwater runoff separately and as part of TMDL planning and implementation.
- MassDEP should explore the feasibility, through its regulations and policies, concerning the potential of natural attenuation as treatment option for use by cities and town in the CWMPs they are under taking for the removal of nitrogen from nitrogen contaminated groundwater plumes.

6.5 Wastewater Management Planning and Reporting

6.5.1 The Problem Defined

The Clean Water Act does not explicitly require implementation of CWMPs as a TMDL requirement. However, state and local permits are ultimately affected by TMDL compliance requirements; including the groundwater discharge permits the Commonwealth issues and the local Board of Health approvals for the installation of on-site wastewater treatment and disposal systems. The following identifies implementation challenges for the Towns as well as MassDEP particularly as it relates to the implementation of nonpoint source control reductions and watershed-based solutions.

6.5.2 Challenges to Watershed-Wide Planning and TMDL Implementation

6.5.2.1 Massachusetts Towns

- Inter-municipal collaboration on CWMP planning and implementation on a watershed basis.
- Follow through on MassDEP approved CWMPs: Some towns fail to complete their plans, or to modify them without MassDEP consultation or consult with the towns sharing the watershed.
- MassDEP should provide greater clarity in its expectations for all levels of CWMP planning, implementation, water quality monitoring, and adaptive management.
- Concern that towns should be doing more locally, using their permitting, licensing, and enforcement authority to control existing and future NPS discharges to nitrogen-sensitive embayments.

6.5.2.2 MassDEP

- Tracking Progress of TMDL Implementation Plans
- Enforcement of TMDLs for nonpoint sources, as TMDLs are federal Clean Water Act requirements for point source discharges, via NPDES permits, and the Commonwealth's powers under the Clean Waters Act.
- Promoting proactive voluntary actions through encouragement, financial support, and guidance.

6.5.2.3 Proposed Solutions

- MassDEP should provide cities and towns guidelines that promote coordinated watershed-wide planning and reporting among multiple towns sharing a coastal watershed.

- MassDEP should consider revising its requirements for a MassDEP approved CWMP that the applicants demonstrate intermunicipal collaboration and problem solving for the nitrogen reductions required from the coastal watershed.
- The Nitrogen Sensitive Area designation under Title 5 should be revised to address the specific coastal watershed load and the needs for estuarine water quality restoration. Currently Title 5 is a blunt instrument that may not fully address specific local conditions and needs.
- MassDEP should consider using the groundwater discharge permit program for the implementation of the approved CWMPs that address nitrogen load reductions in nitrogen sensitive estuaries. Provisions should be provided that define specific reporting requirements that track and report watershed-wide improvements, and the water quality improvements that have been monitored in the estuary through an approved water quality monitoring and reporting program.
- MassDEP should require more Nutrient Management Plans. One was required for the groundwater discharge permit that was issued to the new wastewater treatment facility for the Town of Plymouth in the Eel River Watershed – a coastal watershed to Plymouth Harbor. This requirement was in response to citizen concerns about the discharge's impacts to the Eel River. As a result, Plymouth was required to develop a nutrient management plan as a condition of the town's wastewater treatment plant permit.
- Towns that are undergoing the CWMP process should address the nitrogen load reductions that have been defined on the MEP Technical and TMDL Reports for the targeted threshold concentration that should be achieved in the estuary's sentinel station. This is best accomplished inter-municipally, as all towns are equally responsible for reducing the loads affecting the embayment. Identifying a scenario that best achieves the nitrogen reduction from a cost and environmental perspective is one that cities and towns understand, especially when the scenario that best achieves the required reduction is the most cost effective.
- MassDEP should consider a voluntary approach to wastewater management planning for cash strapped communities, by allowing them to become engaged as part of a step-by-step process, with MassDEP technical assistance and oversight.
- MassDEP should consider the development of simplified plans that address the required load reductions that could be prepared at low cost by regional environmental or planning associations.

6.5.3 Suggested Elements of a Watershed Based CWMP

- Watershed Coordination and Planning
  - Coordination of planning with other towns, regional entities, private stakeholders, and MassDEP to ensure public involvement and intermunicipal coordination).
  - Local decisions on allocation of assimilative capacity and final TMDLs for subembayments
- Actions to meet the TMDL
  - List of actions to be taken individually or jointly; i.e., elements of town CWMP that impact the specific estuary
  - Identification of responsible parties
  - Actions should include both voluntary and regulated
- Timeframe for actions and expected timeframe for meeting TMDLs
- Monitoring progress toward the TMDL and adaptive management
  - Responsibility for water quality and other monitoring
  - Schedule for distributing results to stakeholders and to MassDEP
  - Steps to be taken if plan or TMDL need revisiting

Chapter 7: MassDEP Action Plan to Facilitate CWRMP Planning and Implementation by Coastal Communities

The views and recommendations presented in the preceding Chapter identify a number of issues that the stakeholders would like MassDEP to address. They are perceived as barriers and/or regulatory hurdles or gaps in their understanding and of issues the Department should address to help expedite municipal planning and implementation of the nitrogen management plans they will undertake either alone or in collaboration with the towns sharing the watershed.

Stakeholders are of the opinion that MassDEP should do more to help facilitate CWRMP planning by improving their knowledge through the publication of guidance documents and improving regulatory pathways through new and/or amended polices regulations or statutes that clearly address the issues they have identified for resolution.

In view of these comments, MassDEP proposes to undertake the following actions within the time frames presented. These include:

- Outreach and Technical Assistance
- Nitrogen Management Planning and Implementation
- TMDL Compliance Monitoring and Reporting
- Adaptive Management

ACTION PLAN

7.1. Outreach and Technical Assistance

Develop educational workshops on nitrogen management planning and implementation through the CWRMP process to coastal communities sharing a watershed to a water quality impaired estuary:

Action Item: MassDEP: Prepare guidance for use by stakeholders and town officials to promote an understanding of nitrogen pollution impacts, the vocabulary and science underlying the MEP Technical Report, and the load reductions for nitrogen management planning and implementation. The MEP Process is a long-term TMDL planning and implementation process beginning with scientific water quality monitoring, hydrologic and landuse assessments, and modeling to determine the watershed sources and loads of nitrogen, and its Total Maximum Daily Load (TMDL) – the maximum watershed load of nitrogen that the estuary can absorb and remain healthy, and the amount that must be removed to restore water quality to the critical nitrogen threshold.
Target Date: December 2009

Action Item: MassDEP: Municipal Outreach Workshops/Meetings will be scheduled to:

- MassDEP will increase the number of its public presentations and/or outreach to the public that introduce the MEP Technical Reports through its TMDL public presentations and through other venues as needed for an appreciation of its scientific approach and significance for watershed-wide planning and implementation.
- Promote Benefits of coordinated intermunicipal CWRMP watershed-based planning

Target Date: As reports are completed

7.2. Nitrogen Planning and Implementation

The federal Clean Water Act and MassDEP's Water Quality Standards require that water bodies in the Commonwealth meet their designated uses (recreational fishing, swimming and boating and as habitat for sustaining eelgrass meadows as a breeding and nursery ground for important commercial marine fisheries and shellfish). Since most of the MEP embayments do not meet surface water quality standards, every effort must be made through nitrogen management planning and implementation to restore water and habitat quality in the estuary so that the identified maximum daily loads of nitrogen being discharged from the watershed are not exceeded; and if they are, they must be reduced so that the target threshold concentration at the sentinel station(s) in the estuary is met.

7.2.1 Nitrogen Management Planning

The issues addressed in a watershed CWRMP are the same as those addressed in a town CWRMP: current and future conditions for water resources, identifying key problems, developing and evaluating possible solutions, and recommending the preferred alternative. The only difference is where the borders of the study are drawn.

CWRMP planning will require less time and will be the most effective if towns take a leadership role and work together voluntarily. This mindset is beginning to take place as towns get the Technical Reports and TMDLs that document the negative impacts of nitrogen pollution and the importance of getting started on solutions.

Mass DEP will continue to encourage a voluntary, cooperative approach as long as towns are making progress. MassDEP will support towns by providing input and guidance, providing SRF funds and other incentives, and ensuring that state regulations and policies aren't unnecessary barriers to good solutions. If progress stalls, there are other, less flexible approaches available to ensure progress, based on the state's regulatory and statutory authority.

Communities are looking for interim measures to address the impacts of continued growth prior to CWMP implementation.

Action Item: Until corrective actions through a MassDEP approved CWRMP are implemented, MassDEP will define interim measures to accommodate new, growth-related discharges in nitrogen-sensitive watersheds which MassDEP permits.

Target Date: June 2009

Action Item: MassDEP will develop guidance, identifying appropriate incentives for consideration by towns to encourage intermunicipal, watershed-wide planning on how to develop a coordinated watershed-wide Nitrogen Management Plan.

Target Date: December 2010

7.2.2 Permitting

Mass DEP is not advocating one particular template because there is no single approach that will work for every watershed. In addition, towns may need to change their approach over time, if local conditions and goals change. Many factors will influence the decision on the best approach, including

- Nitrogen issues specific to the watershed
- Options chosen to reduce nitrogen loads
- Towns' experience working with each other.

7.2.3 CWRMP Implementation

MassDEP's preferred course of action is to work with the towns to promote nutrient management planning and implementation of preferred alternatives through either a CWMP for waste management or a CWRMP to also include management of stormwater and fertilizer use. However, for communities sharing a coastal watershed that do not engage in appropriate planning and implementation in a timely fashion, MassDEP reserves the right to exercise its enforcement authority to require compliance pursuant to all applicable federal and state statutes and regulations.

Action Item: MassDEP will identify appropriate triggers for compliance and develop the necessary enforcement strategy.

Target Date: December 2009

7.2.4 TMDL Compliance Monitoring and Reporting

7.2.1.1 TMDL Compliance

CWRMPs identify the appropriate actions and timelines to achieve TMDL compliance. Adherence to the actions and timelines identified in the MassDEP approved CWRMP will determine if the community/communities are in compliance with the water quality standards.

Action Item: MassDEP will define the compliance strategies that incorporate milestones within the MassDEP approved CWRMP.

Target Date: December 2009

7.2.1.2 Compliance Monitoring and Reporting

MassDEP approved CWRMPs will identify compliance monitoring programs to assess if the nitrogen reductions from CWRMP implementation have improved water quality and habitat conditions. A compliance monitoring program will assess eelgrass habitat and water quality conditions at the sentinel stations identified in the MEP Technical Report and at other locations, as necessary, including benthic infaunal habitat.

Action Item: MassDEP will describe the detailed components of a model compliance monitoring program that consists of: 1) tracking on the ground actions and compliance with the schedules outlined in the CWMP and 2) ambient water quality and habitat monitoring.

Target Date: December 2009

Action Item: MassDEP will investigate potential protocols and the necessary tools to store and track the monitoring data for use in determining if the pollution reductions have been successful in restoring habitat conditions.

Target Date: December 2009

7.2.5 TMDL Compliance Monitoring and Reporting

MassDEP and EPA recognize that restoring polluted waters is a long-term process, particularly when groundwater is polluted by nonpoint sources. For this reason, MassDEP supports an adaptive management approach to implementing a TMDL. Recognizing that adjustments to the implementation strategy may be required over the CWRMP planning horizon, MassDEP will consider modifications to the CWRMP when compliance monitoring data reflects the restoration of habitat.

In some situations, if habitat has been successfully restored and water quality standards are met prior to full implementation of the MassDEP CWRMP, MassDEP may elect to forego further implementation.

In other situations, if full CWRMP implementation does not achieve the anticipated improvement (in water quality standards and habitat restoration), further measures may be required.

Action Item: MassDEP will develop an adaptive management policy that will identify appropriate criteria under which CWRMP targets or milestones may be modified based on the monitored ecological response to implementation measures.

Target Date: June 2010

Chapter 8: Inter-municipal, Watershed-Wide Comprehensive Wastewater Management Planning Process

Nitrogen pollution is a major environmental and economic problem for Massachusetts's estuaries. MassDEP believes that when people understand the seriousness of the problem they will work together on solutions. The MassDEP is convinced that the most cost-effective way to make progress is for towns to work together, voluntarily, to develop and implement inter-municipal watershed-based solutions.

Water quality impaired estuaries have one feature in common. Most watershed pollutant loads originate from more than one town. MassDEP encourages towns sharing a watershed to establish a working group to identify and address the watershed loads that have been defined for reduction by the MEP Technical Reports. Once these technical reports are prepared, MassDEP will develop a Total Maximum Daily Load (TMDL) that will establish limits on the amount of nitrogen that may be discharged directly or indirectly into each estuary in order to restore these estuaries and return them to compliance with the state's water quality standards.

A watershed-wide CWRMP is the ideal option for coordinated, inter-municipal planning and implementation (Appendix W). It might be structured in one of several ways listed below.

- A watershed-based plan written specifically for a group of towns.
- One document that pulls together relevant information from several towns' plans.
- One town's plan that addresses watershed-wide issues and contains input from other towns in the watershed.

The issues addressed in a watershed CWRMP are the same as those addressed in town plans: current and future conditions of water resources, identification of key problems and possible solutions, and recommendation of the preferred alternative. These are discussed in greater detail in the following MassDEP guidance documents:

- Comprehensive Wastewater Management Plans
  http://www.mass.gov/dep/water/laws/wwtrfpg.pdf

- Water Resource Management Planning
  http://www.mass.gov/dep/water/laws/iwrmp.pdf

Although shared planning is easiest for towns initiating their planning at the same time, most MEP towns are at different stages. In these cases, coordination is even more important. Towns can take the following steps:

- Initiate discussions with neighboring communities and identify a consultant when the MEP Technical and TMDL reports have been completed. Retain the services of a consultant to provide the support needed to explain the meaning of these documents and their linkage to the preparation of a CWMP (Appendix F). Towns should begin the process by jointly reviewing the MEP Technical and TMDL reports to identify the reduction levels required by the towns. Discuss shared concerns, and submit joint comments on the draft MEP Technical Report. Discussions and decisions concerning cost-sharing will take place regardless of engagement in the formal planning process.
- Schedule inter-municipal briefings on the MEP and Technical Reports which includes MEP's presentations of findings and recommendations for inter-municipal planning.

- Towns can assess nitrogen loading and the allocation of loads to include a town-by-town break down of the unattenuated and attenuated nitrogen loads at current and future build-out conditions within its town borders (Table 3.8). This information will be helpful in negotiating the allocation of responsibility when deciding the reduction of watershed-based nitrogen loads and also for exploring the potential for nitrogen trading, as the basis of reducing the watershed loads have been identified through the MEP process. The detailed science-based information that is now available through the MEP provides towns, for the first time, to explore the potential of nutrient trading for the controllable loads from nonpoint sources of pollution (septic, fertilizer use, and stormwater runoff) - the nation's leading cause of water quality impairment. For more on nutrient trading, local officials and interested stakeholders should familiarize themselves with the EPA guidance on this topic at http://www.epa.gov/owow/watershed/trading.htm. It was too early in the planning and implementation process for the three case studies to explore the potential of this option because planning had not gone far enough to explore how the load reductions would be jointly shared by the towns.
- Discuss the potential role of natural attenuation as part of the planning process for nitrogen removal.
- Based on the nitrogen load for each sub-watershed (Appendix E), identify the wastewater treatment options and locations that best achieve the threshold concentration at the sentinel station(s) in the embayment that is the most cost and environmental effective for the participating communities. Several scenarios should be explored until one is chosen that takes into account the role of natural attenuation, an appropriate mix of centralized, decentralized and on-site treatment, minimal extent of required treatment and potential discharge locations that are the most cost and environmental effective. This coordinated intermunicipal approach to identify solutions that are mutually beneficial prevents redundancy in planning, unnecessary treatment when a mutual agreement could be an option for deciding if treatment in an adjoining community is the most cost effective, and locating treatment options only where needed to restore water quality to the threshold concentration at the sentinel station(s).
- Following these scenario runs that define the best nitrogen removal options and locations for the required reductions, prepare and establish a formal working relationship through a memorandum of understanding (MOU) if it's in your community's financial interest to jointly submit a CWMP proposal to MassDEP for SRF funding support.
- Coordinate formal planning and construction schedules where possible, or at least share information on individual plans.
- When formal planning begins, appoint Citizens' Advisory Committee (CAC) members from other towns that share the estuary, as Mashpee has done.
- Create a joint written record of mutual decisions and a schedule of key points down the road at which coordination will be needed.
- For towns with two or more sub-embayments within its town borders, a town-wide plan should be pursued for implementation. In these cases, communities should delay any final decision for shared-watershed planning.
- In conjunction with wastewater management planning, towns should also adopt zoning and non zoning regulatory controls for use in a nitrogen reduction program for coastal groundwatersheds with a TMDL and for the protection of embayments that have not been impaired (Chapter 5.2; Appendices R-V).

Towns that are ready to initiate their planning should not have to wait for the communities within the same watershed that are not ready. Towns that are unable to collaborate in the planning process when their neighbors are able may find that their planning and cost-saving options may be limited by the decisions made by the towns that began working together early in the process.

Finally, all plans when completed must undergo a public process prior to their adoption and funding. The actions identified in a CWMP to mitigate the impacts affecting coastal embayments will require an unprecedented education and outreach campaign to promote public support to address the required nitrogen load reductions: the largest remaining water quality problem in much of unsewered southeastern Massachusetts. The public process will need to address public perceptions of the problem while informing or motivating stakeholders to promote the proposed management activities.

As described earlier, the NPS impact from residential onsite wastewater systems is substantial; in excess of 70 percent from all sources and greater than 80 percent of all controllable loads within a coastal watershed, including the daily use of lawn fertilizers, or the manner in which stormwater is channeled offsite.

Several sources of information exist for use by local governments and watershed and citizen groups to assist them maximize the effectiveness of their public education and outreach campaigns, these include the following:

"Priorities for Coastal Ecosystem Science" by the Committee to Identify High-Priority Science to Meet National Coastal Needs (National Research Council (1994)). This book provides additional supporting information – describing the critical environmental issues that face coastal ocean and Great Lakes areas, including eutrophication, habitat modification, hydrologic and hydrodynamic disruption, exploitation of resources, toxic effects on ecosystems and humans, introduction of non-indigenous species and global climate change, among others (see: http://www.nap.edu/openbook.php?record_id=4932&page=R1.

"Getting in Step: A Guide for Conducting Watershed Outreach Campaigns" (EPA 2003) is designed to walk watershed groups, municipalities, etc., through the process of developing and implementing a watershed outreach campaign. The guide takes people through a comprehensive six-step outreach process, from establishing goals to project evaluation.
http://www.epa.gov/owow/watershed/outreach/documents/getnstep.pdf

"Getting Your Feet Wet with Social Marketing: Steps for Promoting Behavior Change in Water Programs" (Utah Department of Agriculture 2006) by Jack Wilbur should be required reading for any group working on an issue where awareness of the problems and solutions by the target audiences is minimal. http://ag.utah.gov/conservation/GettingYourFeetWet1.pdf

"The Color of Water: Bring Back the Blue", by the Cape Cod Water Protection Collaborative
http://www.capekeepers.org/images/educ_materials/barnstableworkingdraft-1.pdf

"What does your septic system do? What doesn't it do and why does it matter?"
http://www.capekeepers.org/images/educ_materials/capekeepersepticbrochure.pdf

Also consult EPA NonPoint Source Outreach Toolbox Website for many others sources of information: http://www.epa.gov/owow/nps/toolbox/#toolbox

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APPENDIX A

Glossary

Appendix A has been excerpted from MassDEP's Embayment Restoration and Guidance for Implementation Strategies, Massachusetts Estuaries Project. Department of Environmental Protection, Bureau of Resource Protection, Watershed Permitting Program, March 2003.

Aerobic – Condition where free oxygen is present.

Algae Blooms – An overgrowth of phytoplankton in the water resulting from excessive nutrient (nitrogen or phosphorus) levels or other physical and chemical conditions that enable algae to reproduce rapidly. This overgrowth of algae can form scums and mats, and reduce the amount of oxygen in water when they decay.

Anaerobic – Condition where free oxygen is not present or is unavailable

Anthropogenic – Of, relating to, or resulting from the influence of human beings on nature

Aquifers – Geologic formations (rock, sand, or gravel) that are saturated and sufficiently permeable to yield significant quantities of water

Attenuate – Reduce the force, amount, or magnitude

Benthic – Occurring at the bottom of the sea or lake (e.g., benthic organisms)

Benthic Regeneration – The re-growth of organisms on lake or sea floors

Best Management Practices (BMPs) – Conservation practices to reduce nonpoint and point pollution from sources such as construction, agriculture, timber harvesting, marinas, and stormwater.

Biodiversity – Biological diversity in an environment as indicated by the numbers of different species of plants and animals

Biological Assimilation – The process in which nourishment is absorbed into living tissue

Biological Denitrification or **Biologically Mediated Denitrification -** The removal of nitrogen (nitrates, nitrites) via natural (microbial) processes resulting in the release of nitrogen gas into the air

Biomass – A measure of the amount of living matter per unit area or volume of habitat

Biota – A community of plant and animal organisms

BoH – Board of Health

Cluster System – A wastewater collection and treatment system that serves two or more facilities but less that an entire community.

CMR – Code of Massachusetts Regulations

CWMP – Comprehensive Wastewater Management Plan. A CWMP evaluate the community's wastewater infrastructure/management needs,

CWRMP – Comprehensive Water Resources Management Plan. A CWRMP identifies all the community's needs/problems in one sector of its water resource structure, evaluates alternative means of meeting those needs, selects the most cost-effective and environmentally appropriate remedy, and proposes an implementation plan and schedule. There are three types of CWRMPs: Comprehensive Wastewater Management Plans that evaluate the community's wastewater infrastructure/management needs, Comprehensive Water Supply Management Plans that focus on the community's water supply infrastructure and management issues, and Comprehensive Stormwater Management Plans that focus on the community's stormwater management needs.

Critical Resource Area – Localities that have been judged to be essential to the ecological well-being of the environment. They are subject to protection under MGL c. 131.

Cultural Eutrophication – The accelerated aging process of waterbodies resulting from human sources of nutrients that stimulate the growth of aquatic plants and lead to the depletion of dissolved oxygen.

CWA – Federal Clean Water Act

CZM – Massachusetts Office of Coastal Zone Management

Deposition – Process by which pollutants absorbed by the atmosphere are released to land or water through precipitation or wind.

Down Gradient - The direction that ground water flows, similar to "downstream" for surface water.

Ecosystem – The system of living organisms that interact with one another and their physical environment, functioning as an ecological unit.

Effluent – Treated or untreated wastewater from a treatment facility or unit that is discharged into the environment

Embayment – A bay or a conformation resembling a bay. The terms embayment and estuary are used interchangeably in this report.

EOEEA – The Massachusetts Executive Office of Energy & Environmental Affairs

EPA – The United States Environmental Protection Agency

Estuary – Partially enclosed body of water that consists of fresh and saltwater, where the tide meets the river's current. The terms embayment and estuary are used interchangeably in this Guidance.

Eutrophication – A water body's natural aging process caused by enrichment in dissolved nutrients that stimulate the growth of aquatic plant life, usually resulting in the depletion of dissolved oxygen.

Flushing Rates – The time it takes for an entire volume of water to be exchanged, usually expressed in days or years.

GPD – Gallons Per Day

Ground Water – Water below the land surface in a saturated zone

Groundwatershed – an area that contributes water to a particular aquifer or water-bearing zone with an aquifer complex as found on Cape Cod where this water contributes to one of several lenses.

Ground Water Discharge Permit Program – 314 CMR 5.00 requires that discharges of pollutants to the ground waters of the Commonwealth be regulated by DEP pursuant to MGL c.21, § 43, and that the outlets for ground water discharges and the treatment works associated with them also be regulated by MassDEP.

Habitat – An environment in which plants and animals live, feed, find shelter, and reproduce

Innovative/Alternative (I/A) Systems - Advanced on-site wastewater treatment and disposal systems that provide additions or alternatives to one or more of the components of a conventional system while providing at least an equivalent degree of environmental and public health protection. I/A systems are becoming more widely used, particularly for cost-effective upgrades of failing systems on difficult sites that cannot accommodate a conventional system. I/A technologies also are used for enhanced treatment to reduce nitrogen in nitrogen sensitive areas.
Infiltration – Downward movement of water through soil

Integrated Water Resources Management Planning – Planning process to evaluate all technical and management aspects of water and wastewater resources needed for ecological and human health and develop a strategy to meet these needs

Interim Wellhead Protection Areas (IWPA) – Applicable to public water systems using wells or well fields that lack DEP-approved Zone IIs. The IWPA is a half-mile radius measured from the well or wellfield for sources with an approved pumping rate of 100,000 gallons per day or greater.

Invasive Species – Aggressive and spreading plants or animals that do not naturally occur in a specific area and whose introduction may cause economic or environmental harm

Local Residence Time – Average time for water to migrate from a point in a sub-embayment to a point outside the sub-embayment

MassDEP – Massachusetts Department of Environmental Protection

Massachusetts Clean Waters Act – MGL c. 21, § 26-53, which prohibits the discharge of pollutants to waters of the Commonwealth without a permit, unless exempted by regulation

Mean High Water – The mean of all the high water heights observed over the National Tidal Datum Epoch (see National Tidal Datum Epoch).

Mean Low Water - The mean of all the low water heights observed over the National Tidal Datum Epoch (see National Tidal Datum Epoch).

MEP – Massachusetts Estuaries Project

MEPA – Massachusetts Environmental Policy Act

Mg/L or **Mg** $\mathbf{L^{-1}}$ – Milligrams Per Liter

MGD – Million Gallons Per Day

MGL – Massachusetts General Laws

Mitigate – To take corrective action to eliminate pollution or reduce its impact

ML – Milliliter

National Pollutant Discharge Elimination System (NPDES) - A federal permit program that was established in 1972 by the Federal Water Pollution Control Act (also known as the Clean Water Act or CWA). NPDES regulates the discharge of pollutants into waterbodies. Massachusetts is not authorized to administer the NPDES program.

Natural Attenuation – The naturally-occurring retention or attenuation of nitrogen in wetlands or ponds

Nitrate – Component of fertilizer. Considered a broad indicator of the contamination of groundwater, nitrate is the nitrogen species in marine ecosystems that is most responsible for eutrophication.

Nitrite – A salt or ester of nitrous acid. An intermediate oxidation state of nitrogen, between nitrate and ammonia.

Nitrogen Cycle – Continuous cyclic progression of chemical reactions in which atmospheric nitrogen is compounded, dissolved in rain, deposited in the soil, assimilated and metabolized by bacteria and plants, and returned to the atmosphere by organic decomposition.

Nitrogen Loading – The input of nitrogen to estuaries and embayments from natural and anthropogenic sources.

Nitrogen Threshold Concentration – Maximum amount of nitrogen that an estuary or embayment can assimilate without adversely changing its character and use. Also known as the critical nitrogen limit. Reported as kilograms/day (kg/day).

Nitrogen Threshold Levels - the average water column concentration of nitrogen that will support the habitat quality being sought. Reported as milligrams/Liter (mg/L) or Mg N L-1.

Nonpoint Source – Pollution from many diffuse sources that is carried to surface waters by runoff or ground water. Nonpoint source pollution is typically caused by sediment, nutrients, and organic and toxic substances originating from land-use activities and/or the atmosphere.

Nutrient Sink – Waterbodies or wetlands that hold nutrients in the water column or in the sediments, making them either temporarily or permanently unavailable for biological processes.

Nutrient Trading - Strategies/tools to reduce problem pollutants in rivers and streams, lakes, estuaries, and coastlines. Trading allows a wastewater treatment plant, factory, or other facilities that discharge waste into a waterbody to purchase controls of a particular pollutant elsewhere in the watershed, instead of installing tighter controls for that pollutant at the plant or factory.

Nutrients – Any substance required by plants and animals for normal growth and maintenance, e.g., nitrogen and phosphorus.

On-Site Treatment and Disposal System – A natural system or mechanical device used to collect, treat, and discharge or reclaim wastewater from an individual dwelling without the use of community-wide sewers or a centralized treatment facility. It includes a septic tank and a leach field.

Organic Pollutants – Carbon-based pollutants such as proteins, carbohydrates, and fats and oils, present in wastewater.

Pathogen – An agent such as a virus, bacterium, or fungus capable of causing disease.

Point Source – Pollution from discernable confined, and concrete conveyances, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling rock, concentrated animal feeding operation, vessel or other floating craft from which pollutants may be discharged. This term does not include return flows from irrigation agriculture.

Pollutants – Any element or property of sewage, agricultural, industrial, or commercial waste, runoff, leachate, heated effluent, or other matter in whatever form, and whether originating at a point or nonpoint source, that is or may be discharged, drained, or otherwise introduced into any sewage system, treatment works, or waters of the Commonwealth.

Pollution Trading – A regulatory tool that allows pollution sources to reallocate responsibilities for pollution reduction among themselves and find the most cost-effective reduction measures in order to meet regulatory requirements.

PPM – Parts per Million.

Recharge – The return of water to an underground aquifer by natural or artificial means.

Remediation – Corrective action taken to eliminate pollution or reduce its impact.

Residence Time – The average time required for a particle of water or a pollutant to migrate through an estuary.

Salinity – The measure of the salt content of water.

Sediment – Mineral and organic material that settles from suspension in the water column

Septic Tank – A buried tank designed to receive and pre-treat wastewater from individual homes or facilities by separating settleable and floatable solids from wastewater. It is one component of an on-site wastewater treatment and disposal system.

Sewage – The water-carried human or animal wastes from residences, buildings, industrial establishments, or other places, together with such ground water infiltration and surface water as may be present.

SMAST – The University of Massachusetts – Dartmouth, School of Marine Science and Technology

State Revolving Fund (SRF) – This program assists towns, cities, and wastewater districts in the financing of water pollution abatement projects. There are two types of funding through this program: the Clean Water and Drinking Water State Revolving Fund grants (CWSRF and DWSRF). The clean water fund supports low interest loans to help communities build/upgrade wastewater facilities. The drinking water fund supports low interest loans to help communities build/upgrade water treatment systems.

Sub-embayment – Cove within an embayment.

Surface Water - All waters other than ground waters within the jurisdiction of the Commonwealth, including, without limitation, rivers, streams, lakes, ponds, springs, impoundments, estuaries, wetlands, coastal waters and vernal pools

System Residence Time – Average time for water to migrate through an entire estuarine system

Tidal Flushing – The exchange of water from an estuarine system to the waterbody into which it empties

Total Maximum Daily Load (TMDL) – The greatest amount of a pollutant that a waterbody can accept and still meet water quality standards for protecting public health and maintaining the designated beneficial uses of those waters for drinking, swimming, recreation, and fishing.

Turbidity – A measure of soil or organic particles that cloud water and do not allow light rays to pass through.

Water Column – The open-water environment, as distinct from the bed or shore that may be inhabited by marine or fresh water organisms.

Water Quality – Pertaining to the presence and amount of pollutants and other substances in water that impact its ability to meet standards of purity.

Watershed – Normally associated with surface water resources: an area of land that drains downwards towards lower elevations. Drainage pathways generally converge at rivers or lakes, which tend to become progressively larger as the water moves further downstream through the watershed.

Wetlands Protection Act (WPA) – MGL c. 131, § 40. Under the provisions of the Act, no person may remove, fill, dredge, or alter certain resource areas without first filing a Notice of Intent and obtaining an Order of Conditions. The Act requires that the Order contain conditions to contribute to the following interests: protection of public and private surface and ground water supply, flood control, storm damage prevention, prevention of pollution, protection of fisheries, land containing shellfish, and protection of wildlife habitat.

WWTF – Wastewater Treatment Facility

Zone II – That area of an aquifer that contributes water to a well under the most severe pumping and recharge conditions that can be anticipated.

APPENDIX B

The MEP Linked Watershed/Estuary Model Approach to Calculating Nitrogen Thresholds

Introduction

The Department of Environmental Protection (DEP) has adopted a model developed at the University of Massachusetts Dartmouth School of Marine Science and Technology (SMAST) to calculate the capacity of estuaries to assimilate nitrogen and to run predictive scenarios to aid in planning nitrogen reductions. The model uses a linked approach to incorporate hydrodynamics (for flushing characteristics), water quality modeling (for calibration, validation and predictive scenarios), and land use modeling (to determine nitrogen inputs to the embayment or estuary from the contributing watershed). The model also accounts for regeneration of nitrogen from benthic sediments that can impart a significant seasonal impact on the nitrogen flux in a system. Once the model is calibrated and validated to show that it accurately predicts existing conditions, it is used to establish critical nitrogen thresholds that are attainable water quality targets, and to predict the impact of nitrogen reduction measures.

In establishing nitrogen thresholds, it would be ideal if we could input parameters such as dissolved oxygen, chlorophyll, light attenuation and nitrogen (among others) and receive as an output a complete listing of the flora and fauna that could thrive in such an environment. However, this kind of ecological response model does not exist, so we have to rely on more indirect methods to determine loading limits. The two ways employed in the linked model are to use historical records and/or to run a "no-load" scenario.

The historical approach is the less common of the two because it relies on the rare confluence of a good historical record on both eelgrass coverage and water quality data. Eelgrass is a sentinel species indicator of pristine water quality. By correlating eelgrass coverage to nitrogen data in the same period, we can identify the point at which the nitrogen concentration is high enough to initiate eelgrass loss and use that information to determine the nitrogen-loading limit.

In the absence of a complete historical dataset, a water quality model can be used to estimate what the nitrogen concentration should be under "natural conditions". This no-load scenario is the more common method of determining nitrogen-loading limits. Here, all anthropogenic sources of nitrogen are removed as model inputs under the assumption that this will yield the naturally occurring background nitrogen concentration in the water body. The specific characteristics of the watershed will dictate whether this scenario represents attainable water quality or whether there need to be allowances for nitrogen inputs in addition to those from natural sources.

It is important to realize that the model evaluates specific segments of an embayment and not the embayment as a whole. Therefore, there may be different nitrogen thresholds at different points in the embayment. Generally, the upper reaches of the watershed (i.e., farther from the mouth of the estuary) will exhibit poorer water quality than the lower reaches because they are impacted mode by coastline development. Also the type of aquatic fauna can change depending on the conditions in each sub-embayment. For instance, the goal (and thus the required nitrogen concentration) to protect eelgrass will apply only to areas where eelgrass would be expected to grow. Closer to shore where depth and other factors limit the ability for eelgrass to establish a different goal with a higher associated nitrogen concentration may be needed to protect benthic habitat which is less sensitive to nitrogen. Accordingly, attainable water quality goals may be lower for the upper reaches that for lower reaches.

Mass Balance Calculations

The principle of **mass balance** forms the basis of the SMAST model. Mass balance calculations are standard engineering and scientific equations based on the law of conservation of mass. The SMAST model calculates a mass balance for a single component, in this case nitrogen. The control volume is the total volume of water in the embayment or estuary at a specific time.

The principle of mass balance may be stated as:

Rate of accumulation within a control volume	**=**	**Rate of mass input distributed across a control volume**	**-**	**Rate of mass utput across a control volume**	**+**	**Rate of reaction of mass within control volume (can be a positive or negative value)**

Or, more simply as in Equation 1 below:

Accumulation = Input - Output + [Generation - (Consumption + Storage)]

In the context of estuary modeling, these terms consist of the following:

- Input: nitrogen coming into the estuary from such sources as wastewater, fertilizers, stormwater and atmospheric nitrogen. The model also considers nitrogen contributions from background boundary conditions (i.e. the ocean).
- Output: dictated by the flushing characteristics of the system and how nitrogen is physically circulated through the outlet of the system, or is retained due to circulation and tidal patterns.
- Generation: **benthic regeneration of nitrogen**
- Consumption: natural attenuation, **biological assimilation,** and sedimentation.
- Storage: ambient nitrogen in the water column and sediment.

The Accumulation term quantifies how a constituent increases (positive accumulation), decreases (negative accumulation), or maintains a steady state (zero accumulation). In the linked model, an assumption was made that steady state conditions exist over the time period of the model run, because within a given year the inputs will not change significantly. The Accumulation term is set to zero to reflect the steady state assumption. With this assumption, the model will produce accurate results only if all the terms on the right side of the equation cancel each other out.

Although an embayment model is more complex and dynamic in nature because it factors in tidal hydrodynamic influences, the following examples from a hypothetical embayment provide a simplified illustration of mass balance calculations, analysis of the annual nitrogen load, and the impact of nitrogen-reducing measures.

Example 1: Modeling the Nitrogen Load

Assuming an embayment's watershed has an overall land area of 1000 acres (43,560,000 square feet). The waterbody itself is 500 acres (21,780,000 sq. ft.) with an average depth of 10 feet. Therefore, the total volume of the waterbody is 217,800,000 cubic feet. Precipitation averages 40 inches per year and results in an annual recharge of 20 inches. Three years of monitoring data show that the average summer concentration of total nitrogen in the embayment is 0.47 milligrams per liter (mg/L). The embayment opens out to Nantucket Sound, which has an ambient nitrogen concentration of 0.30 mg/L.

We assume nitrogen inputs from wastewater, atmospheric nitrogen, storm water and fertilizers based on 1000 homes in the watershed served by on-site wastewater treatment and disposal systems, a 1.0 million gallon per day wastewater treatment plant discharging 10 mg/L total nitrogen, and 6,000,000 square feet of impervious surfaces (roads, parking lots, etc.). The hydrodynamic model indicates that the input from Nantucket Sound is 750,000 pounds per year (lbs/yr) of nitrogen and the output to the Sound is 775,500 lbs/yr.

Benthic regeneration accounts for 120,000 lbs/yr, biological assimilation and sedimentation for 130,000 lbs/yr and the rate of natural attenuation in the marsh fringes of the embayment is 20%. Because of the location of the marsh fringe, only the plume from the wastewater treatment plant is intercepted.

Calculations are based on annual loadings, as follows:

Inputs:

1. Treatment Plant Wastewater:

   1.0 **MGD** x 10 mg/L x 8.34 lbs · L/MG · mg x 365 days/yr = 30,441 lbs/yr

   (MGD = million gallons per day, MG = million gallons, and 8.34.L/MG.mg is a conversion factor to calculate nitrogen loadings)

2. On-site Systems:

   1000 homes x 2.5 persons/home x 5.9 lbs/person/yr = 14,750 lbs/yr

3. Runoff:

   There is no infiltration from impervious surfaces so we assume 40 in/yr of rainfall at 1.5 mg/L of nitrogen.

   6,000,000 sq. ft. of impervious surface x 40/12 ft/yr x 7.48 gal/cu. ft. x 1.5 mg/L x 1 MG/1 x 10^6 gal x 8.34 lbs · L/MG · mg = 1871 lbs/yr

4. Fertilizer:

   Each home has 2,000 sq. ft. of lawn with an application rate of 3.5 lbs/1,000 sq. ft./yr.

   We assume that 10% of the nitrogen in the fertilizer leaches into the embayment.

   0.10(1,000 homes x 2,000 sq. ft./home x 3.5 lbs/1,000 sq. ft./yr) = 700 lbs/yr

5. Atmospheric Deposition:

40 in/yr of rain falls directly on the embayment. The land contribution is negligible.

21,780,000 sq. ft. x 40/12 ft/yr x 7.48 gal/cu. ft. x 0.05 mg/L x 1 MG/1 x 10^6 gal x 8.34 lbs · L/MG · mg = 226 lbs/yr.

6. Boundary Waterbody (Nantucket Sound):

We know from our hydrodynamic model that the nitrogen coming into the embayment from Nantucket Sound is 750,000 lbs/yr.

Total input: 30,441 + 14,750 + 1871 + 226 + 700 + 750,000 = 797,988 lbs/yr.

Output:

We know from our hydrodynamic model that the output from tidal flushing into Nantucket Sound is 775,500 lbs/yr.

Generation:

Direct measurement of the sediments shows that benthic regeneration is 120,000 lbs/yr.

Consumption through Natural Attenuation and Sedimentation:

Natural attenuation will intercept the land-based nitrogen inputs at a rate of 20%.

0.20(30,441) = 6,088 lbs/yr

Sedimentation includes biomass settling to the bottom. Direct measurement shows this term to be 130,000 lbs/yr.

Storage: Storage is the ambient load of nitrogen in the water column, which we can determine based on the ambient nitrogen concentration of 0.47 mg/L.

(0.47 mg/L x 217,800,000 cu ft x 7.48 gal/cu ft x 1 MG/1 x 10^6 gal x 8.34 lbs · L/MG · mg)/yr

= 6,386 lbs/yr

To calculate the mass balance of nitrogen in the embayment system, we insert the above numbers into our mass balance equation (Equation 1):

Accumulation = Input - Output + [Generation - (Consumption + Storage)]

Because the model assumes a steady state system, the Accumulation term is zero. Therefore, we can rearrange the equation to place the storage term on the left side in order to check that storage equals all the other terms on the right side.

Storage = Input - Output + Generation - Consumption

6,386 = 797,988 – 775,500 + 120,000 – (130,000 + 6,088)

6,386 ~ 6,400

The two terms agree within 1% of each other, so we are satisfied that the mass balance calculations accurately represent conditions in the watershed.

Conclusions from Mass Balance Calculations

We can derive several insights from Example 1. The most obvious is that, even in this simplified example, the linked model is a complex procedure that relies heavily on site-specific measurements within individual embayments. Components such as benthic regeneration, sedimentation and biological assimilation cannot be accurately modeled and require data collected from the embayment system. Hydrodynamic behavior within an embayment system requires a sophisticated computer program to model the circulation patterns, which allow us to predict certain loading terms. Hydrodynamic modeling is also important in the calibration and validation steps of the final model output.

Second, the quality of the waterbody into which the embayment empties sets the lowest limit (or boundary condition) of ambient nitrogen that can be obtained; hence its designation as the boundary condition. In Example 1, this limit is 0.30 mg/L in Nantucket Sound, which is the "feeder" water for the embayment. We cannot expect to reduce nitrogen levels below 0.30 mg/L.

Third, we can see which sources of nitrogen we can control and those that we cannot. If we need to limit nitrogen inputs, our choices are obviously limited to those we can control. We can also analyze the proportional contribution from each source. Example 1 shows that the greatest input of nitrogen is in the tidal exchange coming in from Nantucket Sound, an input we cannot control. The next largest input is wastewater from the treatment plant and on-site systems, which are sources that we can control. In the majority of cases, source reduction efforts will focus on wastewater, because this is the most significant source of nitrogen that we can realistically expect to reduce.

Fourth, discharge locations are very important. In Example 1, the discharge from the wastewater treatment plant is eligible for the 20% credit for natural attenuation, because the salt marsh fringe intercepts the plume. If the marsh fringed the entire embayment, the 20% credit for natural attenuation could apply to more sources of nitrogen. In virtually all watersheds, there are marsh areas that can attenuate nitrogen loadings, but typically they do not extend along the entire shoreline of the embayment. Thus, it is important to locate discharges where natural attenuation can be maximized.

Fifth, tidal flushing significantly affects nitrogen-loading dynamics. The mass balance equation in Example 1 is dominated by the tidal flushing of the embayment system. Tidal input accounts for 750,000 lbs/yr of nitrogen, and 775,500 lbs/yr are flushed out on the tide. Given that the nitrogen concentration is higher in the embayment than in Nantucket Sound and there is a 25,500 lbs/yr difference between the input and output, it would appear that there is significant system residence time in the embayment. The figures further suggest that the outlet to the Sound may be restricted. Appropriate steps for outlet management, which may include dredging, inlet alteration, or culvert improvements, could possibly improve the flushing of the system and increase the amount of nitrogen transported out of the embayment. This may be a lower cost option than improved wastewater treatment or other source reduction measures.

The preceding exercise shows how each element in the linked model contributes to the condition of an embayment and which nitrogen sources are appropriate candidates for reduction efforts. However, before those decisions can be made, we have to know the ambient nitrogen level that will support a healthy ecosystem and how much nitrogen needs to be removed from the watershed.

The ultimate aim of a nitrogen management plan is to restore a eutrophic embayment or estuary to ecological health or to prevent eutrophication in the first place. The ambient water quality in our example, 0.47 mg/L total nitrogen, is not generally indicative of a healthy system. We also know that the theoretical lower limit of 0.30 mg/L in the boundary water is not an attainable goal. To determine the attainable nitrogen loadings, we can use the historical approach or the no-load scenario. If historical eelgrass records are not available a review of records from other nearby embayments can be used to identify the nitrogen concentration where eelgrass beds exist for a similar type of embayment. If historical eelgrass records are not available the watershed model can be used to run a "no-load" scenario (no anthropogenic inputs from wastewater, runoff from impervious surfaces, or fertilizer). The output provides an estimated ambient nitrogen concentration in the embayment that mimics natural conditions. These target limits can then be used to back-calculate the annual load of nitrogen from the watershed that can be safely assimilated within the embayment.

In this simplified example, we assume that the linked model shows that an ambient nitrogen concentration of 0.35 mg/L is necessary to restore eelgrass beds and that the 0.35 mg/L level is attainable. The next step is to evaluate nitrogen-reducing approaches that can achieve the target threshold, as shown below in Example 2.

Example 2: Modeling Nitrogen Reduction Approaches

Known:

a) The ambient nitrogen concentration in the embayment is 0.47 mg/L.

0.47 mg/L x 217.8 million cu.ft. x 7.48 gal/cu. ft. x 8.34 = 6,386 lbs

b) The target concentration is 0.35 mg/L, or 4,755 lbs,

c) Amount that must be reduced = 6,386-4,755 = 1,631 lbs/yr of nitrogen.

Nitrogen Reduction Options:

1. Improved Flushing:

The model shows that improvements to the outlet channel of the embayment can increase flushing from 775,000 lbs/yr to 776,000 lbs/yr. This will reduce nitrogen loading in the embayment by 500 lbs/year

2. Wastewater Treatment: The wastewater treatment plant provides more treatment than a typical septic system and the plume travels through a marsh system that can attenuate 20% of the nitrogen load, thus, removing some of the on-site systems and connecting those homes to the sewer system may be the easiest way to attenuate that nitrogen load.

The wastewater treatment plant discharges 10 mg/L total nitrogen and an on-site system discharges 35 mg/L. The difference of 25 mg/L translates to an annual reduction in mass loadings of 10.5 lbs/yr for each home that is connected to the treatment plant.

25 mg/L x 55 gpd/person x 2.5 persons/home x 1 MGD/10^6 gal x 8.34 x 365 days/yr =

10.5 lb/yr/home

In order to remove 1,131 lbs/yr of nitrogen, an estimated 108 homes would need to be sewered. The additional flow from these homes to the treatment plant is 108 homes x 2.5 persons/home x 55 gpd/person = 14,850 gpd.

We now need to adjust our mass balance terms to see if we meet our target of 0.35 mg/L in the embayment.

On-site systems:

(1,000 – 108) homes x 2.5 persons/home x 5.9 lbs nitrogen/person/yr = 13,157 lbs/yr

Wastewater treatment plant:

1.01485MGD x 10 mg/L x 8.34 x 365 days/yr = 30,893 lbs/yr

Natural attenuation:

0.20 x 30,893 lbs/yr = 6,178 lbs/yr

Our adjusted input term is:

30,893 + 13,157 + 1871 + 226 + 700 + 750,000 = 796,847 lbs/yr

Using our total mass balance equation (Equation 1):

Storage = Input - Output + Generation - Consumption

4,669 = 796,847 – 776,000 + 120,000 – (130,000 + 6,178)

Since the calculated storage term is less than the target storage term of 4,755 lbs/yr, this combination of sewering and improved flushing will achieve our water quality goal.

The full model runs and technical reports for each estuary or estuary segment will include evaluation of other appropriate nitrogen-management approaches such as improved treatment at the wastewater treatment plant, use of nitrogen- reducing on-site systems, reduced fertilizer use, and stormwater controls. In order to keep this example simple, they are not included here.

APPENDIX C

Massachusetts Surface Water Quality Standards

Excerpted from DEP's Embayment Restoration and *Guidance for Implementation Strategies,* Massachusetts Estuaries Project. Department of Environmental Protection, Bureau of Resource Protection, Watershed Permitting Program, March 2003.

The Massachusetts Surface Water Quality Standards 314 CMR 4.00

(http://www.mass.gov/dep/service/regulations/314cmr04.pdf) set forth classifications for coastal and marine waters. These classifications apply standards that are both quantitative and descriptive and, at a minimum, require "good aesthetic value". The three classes are SA, SB and SC. A description of each follows.

Class SA

314 CMR 4.04(4)(a): "These waters are designated as an excellent habitat for fish, other aquatic life and wildlife and for primary and secondary contact recreation. In approved areas, they shall be suitable for shellfish harvesting without depuration (Open Shellfish Areas). These waters shall have excellent aesthetic value." Class SA standards for specific parameters are in the table below:

Parameter	Standard
Dissolved Oxygen	a. Not less than 6.0 mg/L unless background conditions are lower. b. Natural seasonal and daily variations above this level shall be maintained; levels shall not be lowered below 75% of saturation due to a discharge. c. Site-specific criteria may apply where background conditions are lower than specified levels, or to the bottom stratified layer where the Director determines that the designated uses are not impaired.
Temperature	Shall not exceed 85°F or a maximum daily mean of 80°F. A rise in temperature due to a discharge shall not exceed 1.5o F.
PH	Shall be in the range of 6.5 through 8.5 standard units and not more than 0.2 units outside the normally occurring range.
Fecal Coliform	a. Waters approved for shellfishing shall not exceed a geometric mean **MPN** of 14 colonies/100 mL, nor shall more than 10% of the samples exceed an MPN of 43 colonies/100 mL. b. Waters not designated for shellfishing shall not exceed a geometric mean MPN of 200 colonies/100 mL, nor shall more than 10% of the samples exceed an MPN of 400 colonies/100 mL.
Solids	Shall be free from floating, suspended and settleable solids in concentrations or combinations that would impair any use assigned to this class, that would cause any objectionable

Parameter	Standard
	conditions, or that would impair the **benthic biota** or degrade the chemical composition of the bottom.
Color and Turbidity	Shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this class.
Oil and Grease	Shall be free from oil and grease and petrochemicals.
Taste and Odor	None other than of natural origin.

Class SB

314 CMR 4.05(4)(b): "These waters are designated as a habitat for fish, other aquatic life and wildlife and for primary and secondary contact recreation. In approved areas they shall be suitable for shellfish harvesting with depuration (Restricted Shellfish Areas). These waters shall have consistently good aesthetic value." Class SB standards for specific parameters are in the table below:

Parameter	Standard
Dissolved Oxygen	a. Not less than 5.0 mg/L unless background conditions are lower. b. Natural seasonal and daily variations above this level shall be maintained; levels shall not be lowered below 60% of saturation due to a discharge. c. Site-specific criteria may apply where background conditions are lower than specified levels, or to the bottom stratified layer where the Director determines that the designated uses are not impaired.
Temperature	Shall not exceed 85°F or a maximum daily mean of 80°F. The rise in temperature due to a discharge shall not exceed 1.5°F during the summer months (July through September) or 4°F during the winter months (October through June).
PH	Shall be in the range of 6.5 through 8.5 standard units and not more than 0.2 units outside the normally occurring range.
Fecal Coliform	a. Waters approved for shellfishing shall not exceed a geometric mean MPN of 88 colonies/100 mL, nor shall more than 10% of the samples exceed an MPN of 260 colonies/100 mL. b. Waters not designated for shellfishing shall not exceed a geometric mean MPN of 200 colonies/100 mL, nor shall more than 10% of the samples exceed an MPN of 400 colonies/100 mL.
Solids	Shall be free from floating, suspended and settleable solids in concentrations or combinations that would impair any use assigned to this class, that would cause any objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom.

Parameter	Standard
Color and Turbidity	Shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this class.
Oil and Grease	Shall be free from oil and grease and petrochemicals that produce a visible film on the surface of the water, impart an oily taste to the water or an oily or other undesirable taste to the edible portions of aquatic life, coat the banks or bottoms of the water course, or are deleterious or become toxic to aquatic life.
Taste and Odor	None in such concentrations or combinations that are aesthetically objectionable, that would impair any use assigned to this class, or that would cause tainting or undesirable flavors in the edible portions of aquatic life.

Class SC

314 CMR 4.05(4)(c): "These waters are designated as a habitat for fish, other aquatic life and wildlife and for secondary contact recreation. They shall also be suitable for certain industrial cooling and process uses. These waters shall have good aesthetic value." Class SC standards for specific parameters are in the table below:

Parameter	Standard
Dissolved Oxygen	a. Not less than 5.0 mg/L at least 16 hours of any 24-hour period and not less than 4.0 mg/L at any time unless background conditions are lower. b. Natural seasonal and daily variations above this level shall be maintained; levels shall not be lowered below 50% of saturation due to a discharge. c. Site-specific criteria may apply where background conditions are lower than specified levels, or to the bottom stratified layer where the Director determines that the designated uses are not impaired.
Temperature	Shall not exceed 85°F. The increase due to a discharge shall not exceed 5°F.
pH	Shall be in the range of 6.5 through 9.0 standard units and not more than 0.5 units outside the normally occurring range.
Fecal Coliform	Shall not exceed a geometric mean of 1000 colonies/100 mL nor shall 10% of the samples exceed 2000 colonies/100 mL.
Solids	Shall be free from floating, suspended and settleable solids in concentrations or combinations that would impair any use assigned to this class, that would cause any objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom.

Parameter	Standard
Color and Turbidity	Shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this class.
Oil and Grease	Shall be free from oil and grease and petrochemicals that produce a visible film on the surface of the water, impart an oily taste to the water or an oily or other undesirable taste to the edible portions of aquatic life, coat the banks or bottoms of the water course, or are deleterious or become toxic to aquatic life.
Taste and Odor	None in such concentrations or combinations that are aesthetically objectionable, that would impair any use assigned to this class, or that would cause tainting or undesirable flavors in the edible portions of aquatic life.

The Surface Water Quality Standards apply additional minimum criteria to all surface waters:

Parameter	Standard
Aesthetics	All surface waters shall be free from pollutants in concentrations or combinations that settle to form objectionable deposits; float as debris scum or other matter to form nuisances; produce objectionable odor, color, taste or turbidity; or produce undesirable or nuisance species of aquatic life.
Bottom Pollutants or Alterations	All surface waters shall be free from pollutants in concentrations or combinations or from alterations that adversely affect the physical or chemical nature of the bottom, interfere with the propagation of fish or shellfish, or adversely affect populations of non-mobile or sessile benthic organisms.
Nutrients	Shall not exceed the site-specific limits necessary to control accelerated or cultural eutrophication.
Radioactivity	All surface waters shall be free from radioactive substances in concentrations or combinations that would be harmful to human, animal or aquatic life or the most sensitive designated use.
Toxic Pollutants	All surface waters shall be free from toxic substances in concentrations or combinations that would be harmful to human, animal or aquatic life or wildlife. This includes consideration of site-specific limits, human health risk levels and accumulation of pollutants.

APPENDIX D

Massachusetts Ground Water Quality Standards

Excerpted from DEP's Embayment Restoration and Guidance for Implementation Strategies, Massachusetts Estuaries Project. Department of Environmental Protection, Bureau of Resource Protection, Watershed Permitting Program, March 2003.

314 CMR 6.00 establishes the Massachusetts Ground Water Quality Standards http://www.mass.gov/dep/service/regulations/314cmr06.pdf . These standards consist of ground water classifications which designate and assign the uses for which the various ground waters of the Commonwealth shall be maintained and protected. The Standards also include water quality standards necessary to sustain the designated uses and regulations necessary to achieve the designated uses or maintain the existing ground water quality.

All ground waters of the Commonwealth are assigned to Class I, II, or III based upon the most sensitive uses for which the ground water is to be maintained and protected:

- Class I - Ground waters assigned to this class are fresh ground waters found in the saturated zone of unconsolidated deposits or consolidated rock and bed rock and are designated as a source of potable water supply.
- Class II - Ground waters assigned to this class are saline waters found in the saturated zone of the unconsolidated deposits or consolidated rock and bed rock and are designated as a source of potable mineral waters, for conversion to fresh potable waters, as raw material for the manufacture of sodium chloride or its derivatives, or similar products.
- Class III - Ground waters assigned to this class are fresh or saline waters found in the saturated zone of unconsolidated deposits or consolidated rock and bed rock and are designated for uses other than as a source of potable water supply. At a minimum the most sensitive use of these waters shall be as a source of non-potable water that may come in contact with, but is not ingested by, humans.

Class I and Class II Ground Waters. The following minimum criteria are applicable to all Class I and Class II ground waters:

Parameter	Standard
Pathogenic Organisms	Shall not be in amounts sufficient to render the ground waters detrimental to public health and welfare or impair the ground water for use as source of potable water.
Coliform Bacteria	Shall not exceed the maximum contaminant level as stated in the National Interim Primary Drinking Water Standards
Arsenic	Shall not exceed 0.05 mg/l
Barium	Shall not exceed 1.0 mg/l
Cadmium	Shall not exceed 0.01 mg/l
Chromium	Shall not exceed 0.05 mg/l
Copper	Shall not exceed 1.0 mg/l
Fluoride	Shall not exceed 2.4 mg/l
Foaming Agents	Shall not exceed 0.5 mg/l
Iron	Shall not exceed 0.3 mg/l

Parameter	Standard
Lead	Shall not exceed 0.05 mg/l
Manganese	Shall not exceed 0.05 mg/l
Mercury	Shall not exceed 0.002 mg/l
Nitrate Nitrogen (as Nitrogen)	Shall not exceed 10.0 mg/1
Total Trihalomethanes	Shall not exceed 0.1 mg/l
Selenium	Shall not exceed 0.01 mg/l
Silver	Shall not exceed 0.05 mg/l
Sulfate	Shall not exceed 250 mg/l
Zinc	Shall not exceed 5.0 mg/l
Endrin (1,2,3,4,10, 10-hexachloro-1,7-epoxy-1,4,4a,5,6,7,8,9a-octahydro-1,4-endo,endo-5,8-dimethano naphthalene)	Shall not exceed 0.0002 mg/l
Lindane (1,2,3,4,5,6 hexachlorocyclohexane, gamma isomer)	Shall not exceed 0.004 mg/l
Methoxychlor (1,1,1- Trichloro-2, 2-bis (p-methoxyphenyl) ethane)	Shall not exceed 0.1 mg/l
Toxaphene (C10H10C18, Technical Chlorinated Camphene, 67-69 percent chlorine)	Shall not exceed 0.005 mg/l
Chlorophenoxys:2,4-D,(2,4-Dichloro-phenoxyacetic acid)	Shall not exceed 0.1 mg/l
2,4,5-TP Silvex (2,4, 5-Trichlorophenoxy-propionic acid)	Shall not exceed 0.01 mg/l
Radioactivity	Shall not exceed the maximum radionuclide contaminant levels as stated in the National Interim Primary Drinking Water Standards.
pH	Shall be in the range of 6.5-8.5 standard units or not more than 0.2 units outside of the naturally occurring range.
All Other Pollutants	None in such concentrations which in the opinion of the Department would impair the waters for use as a source of potable water or to cause or contribute to a condition in contravention of standards for other classified waters of the Commonwealth.

Class III Ground Waters. The following minimum criteria are applicable to all Class III ground waters:

Parameter	Standard
Pathogenic Organisms	Shall not be in amounts sufficient to render the ground waters detrimental to public health, safety or welfare.
Radioactivity	Shall not exceed the maximum radionuclide contaminant levels as stated in the National Interim Primary Drinking Water Standards.

All Other Pollutants	None in concentrations or combinations which upon exposure to humans will cause death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions or physical deformations or cause any significant adverse effects to the environment, or which would exceed the recommended limits on the most sensitive ground water use.

APPENDIX E

Nitrogen Load Allocations

The MEP Technical Reports for each embayment system provides information on the amount of currently-generated nitrogen impacting the estuary that originates in each watershed, based on parcel-based land use data and assumptions of natural attenuation in ponds, lakes, and streams. The land-use loading calculations are therefore amenable to division by subwatersheds and towns within the watershed. Towns also receive electronic copies of the land use data and that can be used to update current and projected land uses, if they want to calculate other allocations.

The MEP nitrogen load contributions by town serve two purposes. First, they help educate the citizens and town officials in the watershed about their contribution to nitrogen problems in the estuary, regardless of where they live. In addition, contributions of nitrogen at buildout are a good starting point for towns to decide their relative financial responsibility for meeting the TMDL.

Methods of allocating loads have been historically applied to point sources; applying these methodologies to nonpoint sources has not been well studied. Other common methods for allocating point source loads are equal percentage removal of nitrogen and equal effluent concentrations from each point source. However, these allocation methods are harder to apply to nonpoint sources of nitrogen. The allocation methodologies are explained in EPA's Guidance for Water Quality-Based Decisions: The TMDL Process. Ultimately, the towns sharing a watershed to an impacted embayment system will decide among themselves how to apportion financial responsibility. MassDEP recommends that towns make this decision separately from decisions about the most cost-effective load reduction strategies.

Load reduction strategies: There are multiple ways to meet an estuary's nitrogen Total Maximum Daily Load (TMDL), depending on the relative share of nitrogen coming from septic and other on-site systems, natural attenuation, and the hydrodynamics of the estuary. MassDEP believes it is inappropriate for the Commonwealth to predetermine scenarios and solutions a town or towns should use to meet the estuary TMDL. Each estuary's Technical Report and TMDL includes one scenario that shows the order of magnitude reductions needed to meet the nitrogen and biological thresholds, but this scenario may not be the most cost-effective one when all options are studied.

An accurate and fair calculation of load reductions depends upon information and decisions that only towns can provide: future land use and pace of development, land banking efforts, future changes in the effectiveness of septic system and community treatment plants to remove nitrogen, and other nitrogen reduction solutions that towns pursue. For any reduction scenario, the relevant variables for each town must be combined and their interactions modeled to determine if the TMDL is achieved. Towns are likely to need multiple rounds of modeling during their planning process or in a separate effort.

MEP experience to date supports the following general guidelines for towns as they collaborate on the most cost-effective restoration strategy:

- Wastewater from septic and advanced on-site systems contributes more than half of the estuary's pollution problems. TMDLs will not be met without addressing this source.
- All sources of nitrogen (including wastewater treatment plants, fertilizers, and stormwater) and reduction strategies should be evaluated to find the most cost effective, environmentally appropriate, and practical way to achieve the threshold concentration at the sentinel station for compliance with the TMDL. MassDEP's

MEP Embayment Restoration and Guidance for Implementation Strategies provides basic information on sources and reduction strategies.

Different scenarios may apportion load reductions in very different ways among towns. For example, the most cost-effective scenario for the watershed as a whole may concentrate wastewater treatment facilities in a few subwatersheds closest to the estuary where natural attenuation is the least effective and where housing densities are the greatest. Nevertheless, the towns sharing a watershed whose wastewater is treated can share the use and cost of their facilities with those where treatment is not available. Agreeing on a method for allocating financial responsibility allows towns to trade among themselves the type and location of each nitrogen reduction strategy.

Nutrient trading is a term commonly used to describe these types of arrangements. Trading is described MassDEP's Implementation Guidance as well as in EPA's Water Quality Trading Assessment Handbook.

APPENDIX F

Massachusetts Estuaries Project

Restoring the Estuaries of Southeastern Massachusetts

Comprehensive Wastewater Management Planning (CWMP) Implementing Nitrogen TMDLs

(Total Maximum Daily Loads)

Massachusetts Department of Environmental Protection
One Winter Street
Boston, MA 02108

Commonwealth of Massachusetts:
Devall Patrick, Governor

Executive Office of Energy and Environmental Affairs:
Ian A. Bowles, Secretary

Department of Environmental Protection:
Laurie Burt, Commissioner

March 2008

What is a CWMP? Comprehensive wastewater management planning is a locally managed, community-wide process that evaluates current and future wastewater needs, compares alternate solutions, and chooses a final plan based on cost effectiveness and environmental impact. The resulting document is called a Comprehensive Wastewater Management Plan, or CWMP.

A CWMP is a key step toward implementation of Total Maximum Daily Loads (TMDLs) for nitrogen in southeastern Massachusetts' estuaries. Meeting the TMDLs will reduce the nitrogen pollution that is causing poor water quality. The MassDEP fact sheet on TMDLs provides background information on the harmful effects of nitrogen in coastal ecosystems and the importance of protecting and restoring nitrogen-impaired estuaries.

Is a CWMP required to implement a TMDL? Does a CWMP have to indicate that the nitrogen TMDL will be met?
With the exception of enforcement cases, a CWMP is not a formal requirement for implementation of a TMDL. However, MassDEP strongly encourages communities to develop sound plans that include public participation in order to implement a TMDL, and the CWMP is an excellent community-wide process for this purpose. TMDLs limited to a part of a town could use a less comprehensive process, provided that the essential planning and public participation steps are included.

Projects based on a CWMP or equivalent plan are significantly more likely to get financial support from the State Revolving Fund (SRF) Program.

The CWMP or other plan must describe the proposed nitrogen reductions to meet the TMDL.

For watersheds that cross municipal boundaries, will each community prepare its own CWMP or should there be a watershed-wide CWMP?
MassDEP encourages communities to work together to solve common environmental problems through a watershed-wide CWMP. At the very least, communities should jointly develop a process that identifies and evaluates alternatives, as “what if scenarios” using the MEP Linked Model, until the most cost-effective nitrogen reduction alternative on a watershed-wide basis is chosen.

What if the nitrogen TMDL targets change over time? How is this reflected in the CWMP?
If a major change occurs, the CWMP can be revised. TMDLs are based on long-term solutions, therefore adaptive management should be considered as new information based on monitoring or additional modeling becomes available to address shortcomings with the CWMP’s implementation

Who is involved in developing a CWMP?
Typically, a municipality will convene a committee of local officials, stakeholder groups, and citizens that works with an engineering consultant to develop the CWMP. It is MassDEP’s

experience that the town's residents should be brought into the CWMP process through a combination of public outreach and advisory groups.

Does the state have to approve a CWMP?
To be eligible for SRF funding for implementation projects, a CWMP must be reviewed and approved by MassDEP. MassDEP's review ensures that nitrogen targets in the TMDL will be met and that the plan addresses other issues in MassDEP's Guide to Comprehensive Wastewater Management Planning. If the MEPA office (Massachusetts Environmental Policy Act) requires an Environmental Impact Review (EIR), MEPA must approve the EIR before MassDEP can approve the CWMP.

Implementation

What is MassDEP's role in TMDL implementation?
Communities will have the lead in the implementation process. However, MassDEP has an obligation to ensure that Massachusetts's waters are protected so that all citizens can enjoy a clean and healthy environment. MassDEP's role will include:

- Support for Community Efforts
  - Meet with communities before beginning a CWMP, to help develop a timeframe, discuss regulatory issues, and determine potential financial support.
  - Work with other regional, state, and federal agencies to ensure coordinated input on the CWMP.

- Financing: Provide SRF funding

- Regulatory Review and Policy Guidance
  - Issue state permits as needed for wastewater facilities.
  - Review MassDEP regulations to ensure that they support estuary restoration, and changes in state regulations and laws if needed.
  - Support watershed permitting and wastewater management districts when communities feel they are appropriate.
  - Monitor CWMP implementation progress toward estuarine ecosystem restoration.

How many years do communities have to implement a TMDL? How long will implementation take?
There are no specific timelines for completing the implementation process, but MassDEP does expect the CWMP to include specific steps and estimated dates for their completion. Ten to fifteen years is a reasonable timeframe for full implementation of all proposed measures, but this will vary widely depending on the amount and source of nitrogen, the complexity and cost of implementation steps, and the mix of solutions proposed.

MassDEP and EPA recognize that restoring polluted waters is a long-term process, particularly when groundwater is polluted by nonpoint sources. For this reason, MassDEP supports an adaptive management approach to implementing a TMDL: taking the most cost-effective measures first, measuring their impact, and making adjustments where necessary. Giving priority to projects with more immediate impacts on water quality will help communities adjust implementation steps if needed.

Smaller community-based or cluster wastewater treatment systems generally take less time to implement than town-wide sewering and treatment plant construction. Smaller projects may require only several years to design and install; large projects can take longer. Several projects often can be underway at once, especially if they are dependent of one another.

The severity of nitrogen pollution in MEP estuaries means that nearly all practical implementation steps will be required.

To whom will MassDEP issue the permits needed to implement a TMDL?
This will vary ending on the estuary. Nitrogen pollution affects entire watersheds, which usually do not follow municipal boundaries. Among the available options, MassDEP is considering issuing watershed-wide permits based on watershed boundaries (e.g., issuing a permit to a district composed of several municipalities or portions of them). Public and private entities controlling or operating treatment facilities will require permits.

In any case, the permittee will have a number of responsibilities:

- Construction of wastewater treatment facilities.
- Ensuring proper operation and maintenance of on-site (septic) systems.
- Funding improvements through fees, betterments, and bonding.
- Monitoring progress toward restoring the estuary.

Depending on the findings of the CWMP, other major sources of nitrogen will also be responsible for reducing their nitrogen loads. These sources may also be issued state permits, or be subject to local controls.

What are market approaches and nutrient trading, and will they help in implementing nitrogen TMDLs?
Market approaches (nutrient trading is one example) are tools that allow different nitrogen sources to reallocate responsibilities for pollution reduction and fund those that meet environmental goals in the most cost-effective manner. For example, sewering will be an important implementation tool, but a combination of nitrogen-reducing on-site systems and conventional septic tanks may be able to meet the TMDL targets in some locations at a lower cost. The CWMP process will ensure that communities evaluate the financial and environmental tradeoffs among all possible nitrogen reduction methods.

Financing

How much will it cost to implement a TMDL?
Costs will end on the extent of nitrogen pollution and the implementation steps identified in the CWMP. However, we do know that restoring and protecting our estuaries will be expensive.

What financial support does the state have to implement TMDLs?
The Massachusetts State Revolving Fund Program (SRF) provides low-interest loans to communities working on water and wastewater improvements, including the development of a CWMP. SRF funds are distributed annually on a competitive basis, based on environmental and public health priorities. SRF funds are the primary source of state support to municipalities for TMDL implementation.

Will MEP community projects that implement a TMDL receive extra SRF points?
Yes. Projects to implement an approved TMDL or to address regional or watershed-wide needs can receive additional points under the existing priority criteria set by MassDEP's Division of Municipal Services. In the future, MassDEP may identify high priority projects such as the MEP to be funded if they meet applicable SRF program requirements.

Can SRF money be used to fund a CWMP and plan TMDL implementation?
Yes. The SRF program currently provides up to 10% of the Clean Water SRF capacity for planning activities. In general, planning funds have been available to all communities that have requested them. Keep in mind, however, that project design is not an eligible expense.

Can SRF money be used to purchase privately owned wastewater treatment facilities?
Yes, provided that the project provides additional capacity to mitigate documented problems

Massachusetts Department of Environmental Protection

and does not promote sprawl. Eligible costs include planning studies, land purchases, and purchase of treatment facilities.

Resources and Contacts

To learn more about how your community is involved in the MEP
In addition, how you can contribute, contact your local Town Hall.

- *Department of Environmental Protection (MassDEP):*
  Massachusetts Estuaries Project: http://mass.gov//water/resources/coastalr.htm. Includes fact sheet on TMDLs, MassDEP's *Guidance for Implementation Strategies*, and Guidelines for Multi-town Collaboration, and MEP Technical Reports.
  Contact: Brian Dudley (508) 946-2753 brian.dudley@state.ma.us.

  Clean Water State Revolving Fund (SRF):
  http://www.mass.gov//water/wastewater/wastewat.htm. Includes Final Facilities Planning Guidance for CWMP development.
  Contact: Steven McCurdy (617) 292-5779 steven.mccurdy@state.ma.us.

  TMDLs: http://www.mass.gov//water/resources/tmdls.htm
  General information on Total Maximum Daily Loads.
  Contact: Kimberly Groff (508) 767-2876 kimberly.groff@state.ma.us.

  Guide to Comprehensive Wastewater Management Planning
  http://www.mass.gov//water/laws/wwtrfpg.pdf

- *Environmental Protection Agency (EPA):*
  Estuaries: http://www.epa.gov/owow/estuaries/
  TMDLs: http://www.epa.gov/OWOW/tmdl/
- *Cape Cod Commission*: www.capecodcommission.org
- Martha's Vineyard Commission: http://almanac.vcsmv.org
- *Southeastern Regional Planning and Economic Development District:* http://www.srpedd.org/
- *Buzzard's Bay Project National Estuaries Program:* www.buzzardsbay.org
- *Coalition for Buzzards Bay:* www.savebuzzardsbay.org
- *Pleasant Bay Alliance*: http://www.pleasantbay.org/
- Three Bays Preservation Association: http://www.3bays.org/

APPENDIX G

TMDL Implementation and SRF Funding Questions and Answers

In what ways does the existing SRF program encourage watershed-wide planning by Towns?

SRF program regulations require that a planning effort of some kind precede any loan. The extent of the planning can be simple for a small rehabilitation job or complex, when a community wants to address wastewater, drinking water and stormwater management issues concurrently. MassDEP regions will periodically require a community to undertake a comprehensive study, if the community encounters widespread and significant problems, but otherwise the level of planning is determined by the community. Municipal Services (the home of the SRF programs) does not dictate what level of planning is required.

Is SRF money available for planning TMDL implementation?

The SRF program currently provides up to 10% of the Clean Water SRF capacity for planning activities. Typically those funds have been available to whoever has requested them. However, project design is not an eligible expense.

Will MEP community projects to implement TMDL receive "extra" SRF points?

Projects that implement a Department approved TMDL can receive an additional 30 points under the existing priority criteria established by the Division of Municipal Services. Additionally, the Department under SRF regulations can identify and solicit "High" priority projects that will receive priority for funding if they meet applicable SRF program requirements. The Department would determine whether MEP projects should receive such a designation.

Does the existing SRF program contain incentives that explicitly encourage Towns to develop CWMPs jointly?

No, it does not. Please do not confuse "SRF program" with MassDEP water resource priorities. SRF is the financing mechanism, not the policy-driver on water resource management issues. The Department's Guide to Water Resources Management Planning, a document to which the SRF program contributed, contains the agency's guidance on municipalities' watershed planning. If the Department's policy is to encourage or require watershed-wide planning, SRF financing decisions will support that direction.

In what ways does the existing SRF program explicitly encourage Towns to implement watershed-wide solutions?

If MassDEP, by policy, regulation, or statute determines that it will explicitly encourage or direct communities to implement watershed-wide planning, the SRF financing decisions will support that direction.

If all else were equal among two Towns, and one was doing watershed-wide planning and one was doing Town-wide planning, would the existing SRF program awards be different for those Towns? If so, what is the rationale for different awards?

There would be no difference in awards. All SRF loans are set by the Mass Legislature at a subsidy equal to 2% interest rate over 20 years. The program has no authority to incentives further. A planning effort that was broader than one municipality's boundaries might earn a few more points than a narrower plan, but if the two proposals had equal numbers of points, that would not be the deciding factor.

Can SRF money be used to purchase privately owned WWTFs?

The answer is yes, with the prime justification that the project provides additional capacity to mitigate documented problems and does not promote sprawl. As a condition of financial assistance, the municipality must first obtain and then retain an ownership interest, such as an easement or a fee simple title, to the facility site and rights of access as will assure undisturbed use and possession for the purpose of construction, operation and maintenance for the estimated life of the project.

Eligible costs include the following:

1. Planning study that includes review of the facility's capacity to accept additional flows;

2. Costs of acquiring all or part of the privately owned WWTFs and appurtenances subject to:

    a. The acquisition, apart from any upgrade, expansion or rehabilitation, provides new pollution control benefits;
    b. The acquired facilities were not built with previous federal or state financial assistance;
    c. The primary purpose of the acquisition is not the reduction, elimination or redistribution of public or private debt; and
    d. The acquisition does not circumvent the requirements of 310CMR44.00, or any other state or local requirements.

3. Land costs, including legal, administrative and engineering costs, where the land itself will be an integral part of the land application treatment process and is acquired in fee simple or by lease or easement.

APPENDIX H

MassDEP Recruitment Letter

[MassDEP Letterhead]

February 17, 2009

Tom Fudala, Town Planner
Town of Mashpee
16 Great Neck Road North
Mashpee, MA 02649

Re: Massachusetts Estuaries Project
Popponesset Pilot Project

Dear Tom,

The Technical Assessment (TA) for Popponesset Bay has been delivered to DEP in draft, and we are gearing up to move forward with the pilot project and plans for implementing nitrogen reduction strategies. To this end, we thought it might be helpful to lay out the course of events we expect to unfold over the next several months.

DEP will review the draft Technical Assessment (TA) prepared by SMAST, and subsequently SMAST will prepare a final Technical Assessment. The final report will serve as the basis for a draft TMDL report for Popponesset Bay. Because it may take several months to both finalize the Technical Assessment and complete a draft TMDL for public comment, and recognizing that we have a long road ahead of us to select viable implementation strategies, we would like to begin meeting soon with the Advisory Group for Popponesset Bay to provide an overview of the Technical Assessment and share as much preliminary information from it as possible. We could also begin discussions of different implementation strategies to reduce the nitrogen load and talk about the public process planned for adoption of the TMDL. We expect that this meeting will be the first of many to digest results of the TA and evaluate alternate nitrogen reduction scenarios.

We are hoping for the first Advisory Group meeting during May, depending on the time you need to finalize membership in the Advisory Group and set a date and place for the meeting. We will be happy to work with you on any of these steps, including scheduling the meeting and sending out letters to the Advisory Group members. We expect you would prefer to have the meeting on the Cape, but we would be happy to have it at DEP offices in Lakeville if you wish.

A key step at this point is to develop the watershed-wide Advisory Group to represent Barnstable, Mashpee, and Sandwich. As we have discussed earlier, the role of the Advisory Group will be to:

- Review initial MEP Technical Assessments and help develop alternate nitrogen reduction scenarios to be evaluated through additional modeling.
- Provide local perspective on regulatory issues raised in the project.
- Incorporate alternate scenarios into nutrient management and facilities planning, where appropriate.

- Provide outreach to the local community on results of case studies and interact with other case study communities on nitrogen reduction issues of mutual interest.

The composition of the Advisory Group rests with the communities in the pilot project, and we know you have already identified some members. At the same time, we wanted to share our experience to date that it's very helpful for the Group to have representation from a broad range of Town offices, including the Board of Selectmen, Board of Health, Public Works or Sewer Department, Planning Department, Conservation Commission, Natural Resources (Shellfish Warden), and any other Town Departments actively working on nitrogen reduction. Consulting engineers will have important roles in the Town's wastewater planning, and it is helpful to have them at the table if they are already working with your community. Local environmental groups will also play an important role in implementing nitrogen reduction strategies, and we would encourage you to think about including key players from these groups.

With representation from all these groups, the Advisory Group could be very large. One option you might want to consider is a smaller core group with another, larger advisory group.

I will call each of you within a week to talk about Advisory Group membership, your thoughts on a meeting schedule, and how we can help. Feel free to call me if that's easier for you.

Sincerely,

Claire I. Barker
Massachusetts Estuaries Project
(617) 556-1128

CC:
Mark Ells, Barnstable
Dave Mason, Sandwich
Sharon Pelosi, DEP
Brian Dudley, DEP
Brian Howes, SMAST

APPENDIX I

SMAST
University of Massachusetts Dartmouth
The School for Marine Science and Technology

Massachusetts
Department of
Environmental
Protection

Massachusetts Estuaries Project

Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Popponesset Bay, Mashpee and Barnstable, Massachusetts

Executive Summary

1. Background

This report presents the results generated from the implementation of the Massachusetts Estuaries Project's Linked Watershed-Embayment Approach to the Popponesset Bay System a on the embayment based upon available water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure. Nitrogen loading thresholds for use as goals for watershed nitrogen management are coastal embayment within the Towns of Mashpee and Barnstable, Massachusetts. Analyses of the Popponesset Bay System was performed to assist the Towns with up-coming nitrogen management decisions associated with the Towns' current and future wastewater planning efforts, as well as wetland restoration, anadromous fish runs, shell fishery, open-space, and harbor maintenance programs. As part of the MEP approach, habitat assessment was conducted the major product of the MEP effort. In this way, the MEP offers a science-based management approach to support the Towns of Mashpee and Barnstable resource planning and decision-making process. The primary products of this effort are: (1) a current quantitative assessment of the nutrient related health of the Popponesset Bay System, (2) identification of all nitrogen sources (and their respective N loads) to Bay waters, (3) nitrogen threshold levels for maintaining Massachusetts Water Quality Standards within embayment waters, (4) analysis of watershed nitrogen loading reduction to achieve the N threshold concentrations in Bay waters, and (5) a functional calibrated and validated Linked Watershed-Embayment modeling tool that can be readily used for evaluation of nitrogen management alternatives (to be developed by the Towns) for the restoration of the Popponesset Bay System.

Wastewater Planning: As increasing numbers of people occupy coastal watersheds, the associated coastal waters receive increasing pollutant loads. Coastal embayments throughout the Commonwealth of Massachusetts (and along the U.S. eastern seaboard) are becoming nutrient enriched. The elevated nutrients levels are primarily related to the land use impacts associated with the increasing population within the coastal zone over the past half-century.

The regional effects of both nutrient loading and bacterial contamination span the spectrum from environmental to socio-economic impacts and have direct consequences to the culture, economy, and tax base of Massachusetts's coastal communities. The primary nutrient causing the increasing impairment of our coastal embayments is nitrogen, with its primary sources being wastewater disposal, and nonpoint source runoff that carries nitrogen (e.g. fertilizers) from a range of other sources. Nitrogen related water quality decline represents one of the most serious threats to the ecological health of the nearshore coastal waters. Coastal embayments, because of their shallow nature and large shoreline area, are generally the first coastal systems to show the effect of nutrient pollution from terrestrial sources.

In particular, the Popponesset Bay System within the Towns of Mashpee and Barnstable is at risk of eutrophication (over enrichment) from enhanced nitrogen loads entering through groundwater and surface water from its increasingly developed watersheds. Eutrophication is a process that occurs naturally and gradually over a period of tens or hundreds of years. However, human-related (anthropogenic) sources of nitrogen may be introduced into ecosystems at an accelerated rate that cannot be easily absorbed, resulting in a phenomenon known as cultural eutrophication. In both marine and freshwater systems, cultural eutrophication results in degraded water quality, adverse impacts to ecosystems, and limits on the use of water resources.

The Town of Mashpee has recognized the severity of the problem of eutrophication and the need for watershed nutrient management and is currently developing a Comprehensive Wastewater Management Plan, which it plans to rapidly implement. The Town of Barnstable has already completed and implemented wastewater planning in other regions of the Town not associated with Popponesset Bay. Both Towns have nutrient management activities related to their tidal embayments, which have been associated with the MEP effort in Popponesset Bay. These groups have recognized that a rigorous scientific approach yielding site-specific nitrogen loading targets was required for decision-making and alternatives analysis. The completion of this multi-step process has taken place under the programmatic umbrella of the Massachusetts Estuaries Project, which is a partnership effort between all MEP collaborators and the Towns. The modeling tools developed as part of this program provide the quantitative information necessary for the Towns' nutrient management groups to predict the impacts on water quality from a variety of proposed management scenarios.

Nitrogen Loading Thresholds and Watershed Nitrogen Management: Realizing the need for scientifically defensible management tools has resulted in a focus on determining the aquatic system's assimilative capacity for nitrogen. The highest-level approach is to directly link the watershed nitrogen inputs with embayment hydrodynamics to produce water quality results that can be validated by water quality monitoring programs. This approach when linked to state-of-the-art habitat assessments yields accurate determination of the "allowable N concentration increase" or "threshold nitrogen concentration". These determined nitrogen concentrations are then directly relatable to the watershed nitrogen loading, which also accounts for the spatial distribution of the nitrogen sources, not just the total load. As such, changes in nitrogen load from differing parts of the embayment watershed can be evaluated relative to the degree to which those load changes drive embayment water column nitrogen concentrations toward the "threshold" for the embayment system. To increase certainty, the "Linked" Model is independently calibrated and validated for each embayment.

Massachusetts Estuaries Project Approach: The Massachusetts Department of Environmental Protection (DEP), the University of Massachusetts – Dartmouth School of Marine Science and Technology (SMAST), and others including the Cape Cod Commission (CCC) have undertaken the task of providing a quantitative tool to communities throughout southeastern Massachusetts (the Linked Watershed-Embayment Management Model) for nutrient management in their coastal embayment systems. Ultimately, use of the Linked Watershed-Embayment Management Model tool by municipalities in the region results in effective screening of nitrogen reduction approaches and eventual restoration and protection of valuable coastal resources. The MEP provides technical guidance in support of policies on nitrogen loading to embayments, wastewater management decisions, and establishment of nitrogen Total Maximum Daily Loads (TMDLs). A TMDL represents the greatest amount of a pollutant that a waterbody can accept and still meet water quality standards for protecting public health and maintaining the designated beneficial uses of those waters for drinking, swimming, recreation and fishing.

The MEP modeling approach assesses available options for meeting selected nitrogen goals that are protective of embayment health and achieve water quality standards.

The core of the Massachusetts Estuaries Project analytical method is the Linked Watershed-Embayment Management Modeling Approach, which links watershed inputs with embayment circulation and nitrogen characteristics.

The Linked Model builds on well-accepted basic watershed nitrogen loading approaches such as those used in the Buzzards Bay Project, the CCC models, and other relevant models. However, the Linked Model differs from other nitrogen management models in that it:

- requires site-specific measurements within each watershed and embayment;
- uses realistic "best-estimates" of nitrogen loads from each land-use (as opposed to loads with built-in "safety factors" like Title 5 design loads);
- spatially distributes the watershed nitrogen loading to the embayment;
- accounts for nitrogen attenuation during transport to the embayment;
- includes a 2D or 3D embayment circulation model depending on embayment structure;
- accounts for basin structure, tidal variations, and dispersion within the embayment;
- includes nitrogen regenerated within the embayment;
- is validated by both independent hydrodynamic, nitrogen concentration, and ecological data;
- is calibrated and validated with field data prior to generation of "what if" scenarios.

The Linked Model Approach's greatest assets are its ability to be clearly calibrated and validated, and its utility as a management tool for testing "what if" scenarios for evaluating watershed nitrogen management options.

For a comprehensive description of the Linked Model, please refer to the *Full Report: Nitrogen Modeling to Support Watershed Management: Comparison of Approaches and Sensitivity Analysis*, available for download at http://www.state.ma.us/dep/smerp/smerp.htm. A more basic discussion of the Linked Model is also provided in Appendix F of the *Massachusetts Estuaries Project Embayment Restoration Guidance for Implementation Strategies*, available for download at http://www.state.ma.us/dep/smerp/smerp.htm. The Linked Model suggests which management solutions will adequately protect or restore embayment water quality by enabling towns to test specific management scenarios and weigh the resulting water quality impact against the cost of that approach. In addition to the management scenarios modeled for this report, the Linked Model can be used to evaluate additional management scenarios and may be updated to reflect future changes in land-use with an embayment watershed or changing embayment characteristics. In addition, since the Model uses a holistic approach (the entire watershed, embayment and tidal source waters), it can be used to evaluate all projects as they relate directly or indirectly to water quality conditions within its geographic boundaries. Unlike many approaches, the Linked Model accounts for nutrient sources, attenuation, and recycling and variations in tidal hydrodynamics and accommodates the spatial distribution of these processes. For an overview of several management scenarios that may be employed to restore embayment water quality, see *Massachusetts Estuaries Project Embayment Restoration Guidance for Implementation Strategies*, available for download at
http://www.state.ma.us/dep/smerp/smerp.htm.

Application of MEP Approach: The Linked Model was applied to the Popponesset Bay embayment system using site-specific data collected by the MEP and water quality data from the Popponesset Bay Water Quality Monitoring Program (see Chapter 2). Evaluation of upland nitrogen loading was conducted by the MEP, data was provided by the Town of Mashpee Planning Department and Town of Barnstable, and watershed boundaries delineated by USGS. This land-use data was used to determine watershed nitrogen loads within Popponesset Bay and its sub-embayments (current and build-out loads are summarized in Table IV-3). Water quality within each sub-embayment is the integration of nitrogen loads with the site-specific estuarine circulation. Therefore, water quality modeling of these tidally influenced estuaries included a thorough evaluation of the hydrodynamics of the estuarine system. Estuarine hydrodynamics control a variety of coastal processes including tidal flushing, pollutant dispersion, tidal currents, sedimentation, erosion, and water levels. Once the hydrodynamics of the system was quantified, transport of nitrogen was evaluated from tidal current information developed by the numerical models.

A two-dimensional depth-averaged hydrodynamic model based upon the tidal currents and water elevations was employed for the Popponesset Bay embayment system. Once the hydrodynamic properties of the estuarine system were computed, two-dimensional water quality model simulations were used to predict the dispersion of the nitrogen at current loading rates. Using standard dispersion relationships for estuarine systems of this type, the water quality model and the hydrodynamic model was then integrated in order to generate estimates regarding the spread of total nitrogen from the site-specific hydrodynamic properties. The distributions of nitrogen loads from watershed sources were determined from land-use analysis while nitrogen entering Mashpee's coastal embayment was quantified by direct measurement of stream nutrient concentrations and freshwater flow, predominantly groundwater, in streams discharging directly to the embayment. Boundary nutrient concentrations in Nantucket Sound source waters were taken from water quality monitoring data. Measurements of current salinity distributions throughout the estuarine waters of Popponesset Bay were used to calibrate the water quality model, with validation using measured nitrogen concentrations (under existing loading conditions). The underlying hydrodynamic model was calibrated and validated independently using water elevations measured in time series throughout the embayment.

MEP Nitrogen Thresholds Analysis: The threshold nitrogen level for an embayment represents the average water column concentration of nitrogen that will support the habitat quality being sought. The water column nitrogen level is ultimately controlled by the watershed nitrogen load and the nitrogen concentration in the inflowing tidal waters (boundary condition). The water column nitrogen concentration is modified by the extent of sediment regeneration. Threshold nitrogen levels for the embayment systems in this study were developed to restore or maintain SA waters or high habitat quality. High habitat quality was defined as supportive of eelgrass and infaunal communities. Dissolved oxygen and chlorophyll a were also considered in the assessment.

The tidally averaged total nitrogen thresholds derived in Section VIII-2 of this report were used to adjust the calibrated constituent transport model developed in Section V of this report. Watershed nitrogen loads were sequentially lowered, using reductions in septic effluent discharges only, until the nitrogen levels reached the threshold levels in each sentinel system within the embayment of interest. Water quality modeling results help to analyze whether a nutrient reduction approach will be effective in meeting a nutrient threshold for a specific embayment. However, the approach for any specific embayment discussed in this report serves as only one manner of achieving the selected threshold level for the sentinel sub-embayment within the estuarine system. The specific examples presented herein do not represent the only method for achieving this goal. It is certain that a more targeted nitrogen reduction program that incorporates more localized wastewater treatment and use of natural attenuation processes will result in the most cost-effective plan for restoring the Popponesset Bay embayment.

The Massachusetts Estuaries Project's thresholds analysis, as presented in this technical report, provides the site-specific nitrogen reduction guidelines for nitrogen management of the Popponesset Bay embayment in the Towns of Mashpee and Barnstable. Future water quality modeling scenarios should be run which incorporate the spectrum of strategies that result in nitrogen loading reduction to the embayment. The MEP analysis has initially focused upon nitrogen loads from on-site septic systems as a test of the potential for achieving the level of total nitrogen reduction for restoration of each embayment system. The concept was that since septic system nitrogen loads generally represent 75%-80% of the watershed load to the Popponesset Bay System and are more manageable than other of the nitrogen sources, the ability to achieve needed reductions through this source is a good gauge of the feasibility for restoration of these systems.

2. Problem Assessment (Current Conditions)

Habitat assessments were conducted on each sub-embayment to Popponesset Bay based upon available water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure. The Popponesset Bay System and its sub-embayments (Pinquickset Cove, Ockway Bay, Shoestring Bay, Mashpee River, Popponesset Bay central basin) showed variations in habitat quality, both between sub-embayments and along the longitudinal axis of the larger sub-embayments such as Shoestring Bay. In general, sub-embayments show declining habitat quality moving from the inlet to the inland-most tidal reaches. This trend is seen in both the nitrogen levels (highest inland), eelgrass distribution, infaunal community stress indicators and community properties, as well as summer dissolved oxygen and chlorophyll a records. The following is a brief synopsis of the present habitat quality within each of the sub-embayments. The underlying quantitative data is presented on nitrogen (Section VI.1.3), oxygen and chlorophyll *a* (Section VII.2), eelgrass (Section VII.3), and benthic infauna (Section VII.4).

Combining the dissolved oxygen and chlorophyll a data yields a clear pattern of nutrient related habitat quality (based on these parameters only). At present, the central basin of Popponesset Bay supports relatively healthy habitat conditions, with consistently high bottom water dissolved oxygen and only modest phytoplankton blooms during summer. In contrast, the other regions of the System have moderate to high levels of nitrogen related impairment. Shoestring Bay shows both periodic oxygen declines and significant phytoplankton blooms, while Ockway Bay has similar oxygen declines, but apparently less phytoplankton biomass. Farther along the gradient in nutrient enrichment is the estuarine region of the Mashpee River, which has extreme oxygen excursions and night-time oxygen depletion on a consistent basis and significant phytoplankton blooms. The major issue with the Mashpee River is the extent to which its structure as a salt marsh system ameliorates the impact of these water quality features. However, even as a salt marsh these levels of chlorophyll a and oxygen excursion indicate a moderate level of impairment. Based upon the dissolved oxygen and chlorophyll data the ranking of the Popponesset Bay System components is as follows:

- Popponesset Bay Central Basin -- high quality
- Popponesset Bay upper/confluence, Shoestring & Ockway Bays
  --significantly impaired
- Mashpee River
  -- significantly impaired to degraded (relative to embayments)
  -- moderately to significantly impaired (relative to salt marshes)

At present, the Popponesset Bay System does not support eelgrass. In addition, to the DEP mapping, this has been confirmed during the various MEP surveys for infauna and sediment sampling and the moored instrument studies. The current lack of eelgrass is expected, given the high chlorophyll a and low dissolved oxygen levels and the water column nitrogen concentrations within this system. However, it appears that a substantial area of the central basin did support an extensive eelgrass bed in 1951. In addition, there were smaller beds within the upper region of the main basin, at the mouth to Shoestring Bay. The spatial distribution of these beds is consistent with the pattern of nitrogen related habitat quality, which is currently observed within the System. However, the 1951 nitrogen levels would have been much lower than present levels given the difference in projected watershed nitrogen loading from

1951 versus 2003 population. It appears that as the Bay became nutrient enriched, that the Popponesset Bay basin could no longer support eelgrass. However, it is likely that if nitrogen loading were to decrease that eelgrass could first be restored in the lower portion of the main basin and with further reductions, be restored to the 1951 pattern.

It is significant that eelgrass was not detected Shoestring Bay and Ockway Bay in the 1951 data. It appears that these sub-embayments are not supportive of this type of habitat. Given the structure of these sub-embayments and their sediment types, it appears that they are natural depositional basins and may not be conducive to supporting rooted macrophytes. The lack of eelgrass in the Mashpee River is consistent with its role as a salt marsh system, which drains completely at low tide in some regions and which is "naturally" organic rich. For these reasons, salt marshes typically do not support eelgrass beds within their main channels.

The Infauna Study indicated that all areas but the lower station within the central basin of Popponesset Bay is presently moderately to severely degraded (Table VII-5). Upper Ockway Bay was found to support the poorest infaunal communities within the System. This is based upon the very low number of species and individuals observed in the sediments of Ockway Bay. Although the 2 species that were found (compared to 31 in the central basin) were indicative of healthy conditions, the low numbers (20's compared to 400-500 typically) indicated that this system is not presently supporting a viable community. The Mashpee River sites supported a higher quality habitat related to its function as a riverine salt marsh. The stress indicator species present were dominated by *Cyathura polita,* which is tolerant of the natural salinity stress that helps to define to this marsh system. However, the total numbers of individuals and diversity was low, indicative of a significantly impaired resource, even as a salt marsh. Shoestring Bay and the uppermost portion of the Popponesset Bay central basin both showed a resource between moderate and significant impairment. The numbers of individuals was generally high (500-600 per 0.018 m^2) representing a moderate number of species. Diversity was also moderate to high and distributed between indicators of healthy and stressed conditions (Table VII-6), again indicative of moderate impairment. In contrast the Lower Popponesset Bay station supports a relatively healthy infaunal community, with nearly double the species of other sites and high numbers of individuals (~500 per 0.018 m^2). The high diversity (H') and general evenness' (E) are consistent with a healthy community. The indication of moderate impairment stems from the presence of stress indicator species. The overall results indicate a system capable of supporting diverse healthy communities in the region nearest the tidal inlet with most of the system having infaunal habitat that is significantly impaired under present nitrogen loading conditions.

3. Conclusions of the Analysis

The threshold nitrogen level for an embayment represents the average water column concentration of nitrogen that will support the habitat quality being sought. The water column nitrogen level is ultimately controlled by the integration of the watershed nitrogen load, the nitrogen concentration in the inflowing tidal waters (boundary condition) and dilution and flushing via tidal flows. The water column nitrogen concentration is modified by the extent of sediment regeneration and by direct atmospheric deposition.

Threshold nitrogen levels for each of the sub-embayment systems in this study were developed to restore or maintain SA waters or high habitat quality. In these systems, high habitat quality was defined as supportive of eelgrass and diverse benthic benthos animal communities. Dissolved oxygen and chlorophyll *a* were also considered in the assessment.

Watershed nitrogen loads (Tables ES-1 and ES-2) for the Towns of Mashpee and Barnstable Popponesset Bay embayment system was comprised primarily of wastewater nitrogen. Land-use and wastewater analysis found that generally about 75%-80% of the watershed nitrogen load to an embayment was from wastewater.

A major finding of the MEP is clearly not a single total nitrogen threshold that can be applied to Massachusetts' estuaries, based upon the results of the Popponesset Bay System and the Pleasant Bay and Nantucket Sound embayments associated with the Town of Chatham. This is almost certainly going to be true for the other embayments within the MEP area, as well.

The threshold nitrogen levels for the Popponesset Bay embayment system were determined as follows:

- The target nitrogen concentration for restoration of eelgrass in this system was determined to be 0.38 mg TN L^{-1}. The value stems from (1) the analysis of Stage Harbor, Chatham which also exchanges tidal water with Nantucket Sound and for which a MEP target has already been set), (2) analysis of nitrogen levels within the vestigial eelgrass bed in adjacent Waquoit Bay, near the inlet (measured TN of 0.395 mg N L^{-1}, tidally corrected <0.38 mg N L^{-1}), and (3) a similar analysis in West Falmouth Harbor. Threshold values relating to eelgrass restoration was based upon these other Cape Cod systems with similar nitrogen dynamics, since there are presently no remaining eelgrass beds within Popponesset Bay (or even adjacent Three Bays).

- The sentinel station was located within the upper region of the central basin to Popponesset Bay and the mouth of Shoestring Bay, at the uppermost eelgrass bed detected in the 1951 data. Under present loading conditions the sentinel station supports a measured nitrogen level at mid-ebb tide of 0.581 mg TN L^{-1} and a tidally corrected average concentration of 0.451 mg TN L^{-1}. This location was selected as a sentinel station because: (1) it was the upper extent of the eelgrass coverage in 1951, (2) restoration of nitrogen conditions supportive of eelgrass at this location will necessarily result in even higher quality conditions throughout the whole of the central basin, and (3) restoration of nitrogen concentrations at this site should result in conditions similar to 1951 within Shoestring and Ockway Bays. Shoestring Bay and Ockway Bay should then be supportive of high quality habitat for benthic infaunal communities

- Based upon sequential reductions in watershed nitrogen loading in the analysis described in the Section VIII-3, the sentinel station achieved an average TN level of 0.371 mg L^{-1} , the mouth of Ockway Bay, 0.376 mg TN L^{-1} and the whole of the Popponesset Bay basin <0.331 mg TN L^{-1}.

The data suggest that there is likely a range of total nitrogen that can support healthy infauna within this system. Since Shoestring and Ockway Bays did not support eelgrass in the 1951 data, evaluation was based upon benthic animal habitat.

- Based upon current conditions, the infaunal analysis (Chapter VII) coupled with the nitrogen data (measured and modeled), indicated that nitrogen levels on the order of 0.4 to 0.5 mg TN L-1 are supportive of high quality infauna habitat within the Popponesset Bay System.

- The results of the Linked Watershed-Embayment modeling indicated that when the nitrogen threshold level is attained at the sentinel station (Section VIII-3), TN levels in Shoestring and Ockway Bays are consistent with high quality infauna habitat; upper to lower Shoestring Bay, 0.522 to 0.412 mg TN L^{-1}; upper Ockway Bay, 0.421 mg TN L^{-1}; and mid to lower Mashpee River, 0.525 to 0.422 mg TN L^{-1}.

- It appears that achieving the nitrogen target at the sentinel station will be restorative of eelgrass habitat throughout the Popponesset Bay central basin and restorative of infaunal habitat throughout Shoestring and Ockway Bays and the lower portion of the Mashpee River.

It is important to note that the analysis of future nitrogen loading to the Popponesset Bay Estuarine system focuses upon additional shifts in land-use from forest/grasslands to residential and commercial development. However, the MEP analysis indicates that significant increases in nitrogen loading can occur under present land-uses, due to shifts in occupancy, shifts from seasonal to year-round usage and increasing use of fertilizers (presently less than half of the parcels use lawn fertilizers). Therefore, watershed-estuarine nitrogen management must include management approaches to prevent increased nitrogen loading from both shifts in land-uses (new sources) and from loading increases of current land-uses. The overarching conclusion of the MEP analysis of the Popponesset Bay Estuarine System is that restoration will necessitate a reduction in the present (2002) nitrogen inputs and management options to negate additional future nitrogen inputs.

Table ES-1. Existing total and sub-embayment nitrogen loads to the estuarine waters of the Popponesset Bay System, observed nitrogen concentrations, and sentinel system threshold nitrogen concentrations. Loads to estuarine waters of Mashpee River and Shoestring Bay include both upper watershed regions contributing to the major rivers (Mashpee River, Santuit River, Quaker Run)and groundwater dominated lower regions.

Sub-embayments	Natural (unaltered) Watershed Load [1] (kg/day)	Present Land Use Load [2] (kg/day)	Present Septic System Load (kg/day)	Present WWTF Load [3] (kg/day)	Present Watershed Load [4] (kg/day)	Present Atmospheric Deposition [5] (kg/day)	Present Benthic Flux (kg/day)	Present Total Load [6] (kg/day)	Observed TN Conc. [7] (mg/L)	Threshold TN Conc. (mg/L)
Popponesset Bay System										
Mashpee River [a]	5.30	8.67[b]	26.46	0.15	34.00	0.66	11.47	46.13	0.958-0.627	--
Shoestring Bay [a]	1.85	7.54	23.00	0.23	30.77	2.23	-11.85	21.15	0.690-0.520	--
Ockway Bay	0.24	0.76	2.39	0	3.15	1.09	1.78	6.02	0.677-0.536	--
Pinquicket Cove	0.11	0.19	0.58	0	0.76	0.29	-0.33	0.72	0.527	--
Popponesset Bay	0.18	1.19	5.57	0	6.76	4.01	-5.04	5.73	0.485-0.422	--
System Total	7.68	18.35	58.00	0.38	75.44	8.28	-3.97	79.75	--	0.380[8]

[1] Assumes entire watershed is forested (i.e., no anthropogenic sources)
[2] Composed of non-wastewater loads, e.g. fertilizer, runoff, present-day natural surfaces and atmospheric deposition to lakes
[3] Existing wastewater treatment facility discharges to groundwater
[4] Composed of combined present-day natural surfaces, fertilizer, runoff, and septic system loadings
[5] Atmospheric deposition to embayment surface only
[6] Composed of natural background, fertilizer, runoff, septic system atmospheric deposition and benthic flux loadings
[7] Average of 1997 – 2003 data; ranges show the upper to lower regions (highest-lowest) of a sub-embayment. Individual yearly means and standard deviations in Table
[8] Threshold for sentinel site located at the upper portion of Popponesset Bay and Mouth of Shoestring Bay (PBh); infaunal “targets” for Shoestring and Ockway Bays in the range of 0.400 – 0.500 were used to “check” the validity of the sentinel threshold value.
[a] Loads to Shoestring Bay and Mashpee River include loads from rivers.
[b] Includes residual plume from the capped Mashpee Landfill (0.39 kg/day).

Table ES-2. Present Watershed Loads, Thresholds Loads, and the percent reductions necessary to achieve the Thresholds Loads for the Popponesset Bay embayment system, Towns of Mashpee and Barnstable, Massachusetts.

Embayment Systems and Sub-Embayments	Present Watershed Load (1) (kg/day)	Target Threshold Watershed Load (2) (kg/day)	Atmospheric Deposition (kg/day)	Benthic Flux (3) (kg/day)	TMDL (4) (kg/day)	Percent watershed load reductions needed to achieve threshold loads
Popponesset Bay System						
Mashpee River	34.00	16.17	0.66	9.43	26.26	-52.4%
Shoestring Bay	30.77	19.71	2.23	-8.73	13.21	-35.9%
Ockway Bay	3.15	0.76	1.09	1.11	2.96	-75.9%
Pinquickset Cove	0.76	0.76	0.29	-0.33	0.72	0.0%
Popponesset Bay	6.76	2.77	4.01	-4.91	1.87	-59.0%

(1) Composed of combined present-day natural surfaces, fertilizer, runoff, and septic system loadings.

(2) Target threshold watershed load is the load from the watershed needed to meet the embayment threshold concentration identified in Table ES-1.

(3) Projected future flux (present rates reduced approximately proportional to watershed load reductions).

(4) Sum of target threshold watershed load, atmospheric deposition load, and benthic flux load.

APPENDIX J

Literature Review of Enhanced Natural Attenuation

Executive Summary (Reprinted from technical report to MassDEP)

We reviewed nearly 200 articles and reports related to natural attenuation of nitrogen in different types of wetlands (bogs, fens, emergent, shrub-scrub, wet meadows, cranberry bogs, forested & open wetlands, salt ponds, marshes and mudflats) and waterbodies (streams, rivers, lakes and ponds). We also reviewed the literature on design for constructed wetlands and reviewed articles that described site modifications that enhance natural attenuation rates. The literature review examined data obtained from model, laboratory, and field projects. The literature indicated that the most effective nitrogen removal from surface and ground water is via denitrification in wetlands, small ponds, large ponds and streams. Vegetative uptake played only a minor role in nitrogen removal. The most important physical characteristics of the wetland or water body that enhanced nitrogen removal are nitrate loading, detention time, anoxic zones, organic carbon, temperature and pH. Specifically, conditions that maximize nitrogen removal include a nitrate loading rate of ~ 2 to 3 mg/l, detention time of about one day in anoxic zones with labile organic carbon, near neutral pH, and temperatures ~ 10° C. We also described the role of climate (wind, rain, season, air and water temperature). Finally, we described wetland modifications that may enhance nitrogen removal from ground and surface waters in Massachusetts.

Executive Summary

Massachusetts has a solid history of wetland protection that recognizes the broad range of functions these systems provide. These wetland systems are often balanced precariously between the uplands and a water body such as river, lake, estuary, or an ocean. While these wetlands are often viewed as fragile, in reality they are quite durable provided they are not physically altered and can sustain their existence because they have adapted to the transitional environment. These systems provide protection for many species of flora and fauna; they provide breeding, nesting, and nursery habitat for many species. They also provide important non-quantifiable functions such as recreational benefits, areas for research and educational programs. Some of the wetlands are valued for their ecological functions, others for their societal functions, and some for both. One of the functions not specifically listed in Massachusetts Wetland Protection Act is the ability of wetlands, ponds, streams and lakes to attenuate nitrogen. As inland and coastal waters have become more polluted with nitrogen, we have learned there are negative effects on both the ecosystem and society.

To counter these negative impacts, both federal and state governments have initiated the Total Maximum Daily Loading (TMDL) program. The Clean Water Act, Section 303, establishes the water quality standards and TMDL programs. A TMDL load is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that amount to the pollutant's sources.

States, Territories, and Tribes set water quality standards. They identify the uses for each waterbody, for example, drinking water supply, primary contact recreation (swimming), secondary contact recreation (boating), and aquatic life support (fishing), and the scientific criteria to support that use. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. The calculation must include a margin of safety to ensure that the waterbody can be used for the purposes the

State has designated. The calculation must also account for seasonal variation in water quality. Nitrogen is considered a primary pollutant under the TMDL program.

The Massachusetts landscape is a mosaic of wetland types that use and transform nitrogen. This report summarizes nitrogen-processing functions for each wetland type and considers whether nitrogen attenuation functions (particularly denitrification) could be enhanced, without damage to a wetland or waterbody, to meet society's goal of reducing nitrogen loading to the coastal ocean.

We conclude that natural nitrogen attenuation projects can be designed and implemented such that the high level of nitrogen (nitrate) carried by stream, rivers, and estuaries can be artificially introduced into some wetlands and waterbodies such that the excess nitrate will be denitrified efficiently with low amounts taken up by plants, stored in sediment or lost to outflow. This discussion does not deal with ammonia since, while nitrate is so soluble that it moves with water flows as if it were water, ammonia attaches to sediments and moves very little until it is oxidized to nitrate.

Introduction

The purpose of this review for the Massachusetts Department of Environmental Protection and the Massachusetts Estuaries Project (MEP) is to document the effectiveness of natural attenuation of nitrogen in different types of wetlands and waterbodies, describe designs and site modifications to enhance existing natural attenuation rates, and list data needs for review of natural attenuation project proposals. Enhanced natural attenuation of nitrogen, in combination with wastewater and stormwater management, may reduce N loading from a watershed to the coastal ocean.

We reviewed 183 published scientific papers and gray literature that assess nitrogen retention or attenuation in freshwater and saltwater wetlands (bogs, fens, emergent, shrub-scrub, wet meadows, cranberry bogs, forested & open wetlands, salt ponds, marshes, mudflats and constructed wetlands) and waterbodies (streams, rivers, lakes and ponds). We focused on geographic areas with characteristics (hydrology, geology, climate, growing seasons, etc.) similar to coastal Massachusetts. From the papers we reviewed, we tabulated wetland/waterbody information relevant to nitrogen retention/attenuation in each article. This information is found in Appendix A (provided in electronic format).

The tabulation includes the following:

2. Physical characteristics: size, water depth and volume, sediment volume, depth, organic content and grain size, stream sinuosity
3. Chemical characteristics: redox potential of sediments; air and water temperature; salinity, water quality (DO, BOD, nutrients, pathogens, presence of other contaminants)
4. Biological characteristics: vegetation and wildlife types, abundance, and densities; potential for algal blooms and eutrophication; seasonality of vegetation
5. Processes and process-related variables: wind levels; sunlight, groundwater and surface water flows; tidal hydrodynamics; flushing rates; residence time.

The tabulation shows that none of the articles had complete information about the physical, chemical, biological and environmental features of the wetlands or waterbodies described. It does provide other researchers with guidance as to which articles may be useful for their specific data needs. This preliminary review allowed us to select a subset of articles for detailed review. **Appendix B** contains bibliographic information for each article, including the published abstract (if available). For the articles most relevant to this discussion, an annotation or summary is provided. Appendix B is organized by wetland or waterbody type so that one may easily see the number of articles, type of information, and range of information used to generate the text below. Rather than referring to all annotated articles in the text describing the various wetland types, we refer readers to the appropriate section of **Appendix B**. There are specific instances in the text where we provide data; those are in standard scientific notation and included here as Cited References.

Required Reading. There are 10 articles that should be read by all. Seitzinger (1988) provides a comprehensive literature review of denitrification in freshwater and coastal marine ecosystems. The other nine papers were published in Ambio (the Journal of the Royal Swedish Academy of Sciences) in September 1994. Jansson et al. (1994a) described how adverse effects of increased nutrient loading began to be noticed in the 1960s, and that there were severe impacts by the 1980s with "algal blooms, expansion of reduced bottom areas with sulfide production and partial extinction of fish and crustacean populations" in the Baltic Sea. The response of Sweden and neighboring countries was to support programs to reduce nitrogen discharge by half by 1996. [It should be noted that this goal was not met.] The measures they proposed were to improve sewage treatment for municipal and industrial discharges, reduce nitrogen inputs from agriculture and forestry, and reduce atmospheric deposition. This led to the studies carried out under a research program: Wetlands and Lakes as Nitrogen Traps reported in the special issue of Ambio.

While these articles cover only fresh water systems, everyone involved in technical review of natural attenuation proposals should read them. One of their conclusions important to Massachusetts nitrogen management policy is: If wetlands and waterbodies covered ~1% of the surface area of a southern Sweden subwatershed, one could expect < 15% of the nitrogen would be attenuated or retained (Jansson et al. 1994a). Using models specific to their watershed, Arheimer and Wittgren (1994) estimated that with ~5% of the watershed as wetlands or waterbodies, one could expect ~50% reduction of the nitrogen reaching the coastal ocean in southern Sweden.

The sources of nitrogen in southern Sweden were estimated to be 50% from agriculture and 30% from the atmosphere. While coastal Massachusetts's communities have some agriculture, the major nitrogen sources in this area include those that result from residential development: on site sewage systems and lawn fertilizer. Nevertheless, the nitrogen retention processes are the same, and these important papers centered on southern Sweden wetlands are applicable to Massachusetts's wetlands.

APPENDIX K

SMAST The School for Marine Science and Technology
University of Massachusetts Dartmouth

Massachusetts Department of Environmental Protection

*************************** MEP Technical Memorandum ****************************

To: **Claire Barker, DEP Pilots Project &**
Popponesset Bay Local Project Team

From: **Brian Howes, SMAST, Technical Director MEP**
Roland Samimy, SMAST, Technical Coordinator MEP
Ed Eichner, Cape Cod Commission
Sean Kelley, Applied Coastal Research & Engineering

RE: **Popponesset Bay: Results Pilots Modeling Scenarios - Final,**

Date: **May 2, 2006, Final Revision June 15, 2006**

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The present DEP/SMAST Massachusetts Estuaries Project Technical Memorandum provides the results of the modeling scenarios performed by the MEP Technical Team in support of the Pilots Project efforts regarding the Popponesset Bay System. The Modeling Scenarios followed were based upon discussions with the Popponesset Bay Local Project Team on 1/31/06 in Mashpee Town Hall. The specific scenarios were refined and presented in the MEP Technical Memorandum of 2/21/06. Note that the consensus of the Local Project Team was followed, except as directed by Barker in the email of 2/3/06, regarding Scenario #1. This final version of the MEP Technical Memorandum includes revisions based upon the written comments from the Project Team (4/20/06), discussion at the meeting at Mashpee Town Hall on 4/26/06 where the modeling results were presented, and final written comments (4/28/06). While a formal response to comments document is not required, the Technical Team has provided one in Appendix B.

The modeling was conducted using the previously calibrated and validated Linked Watershed-Embayment Model for the Popponesset Bay System (Report of September 2004). All modeling scenarios focused on reducing nitrogen loading from the watershed to the Popponesset Bay Estuary. The “effect” of each nitrogen loading manipulation is judged by evaluating changes in the total nitrogen levels at critical locations within the estuary itself. The locations selected are the sentinel station (PBh) for eelgrass restoration within the main basin of Popponesset Bay and individual or combinations of stations related to infaunal habitat restoration within the 3 main tributary sub-embayments, Mashpee River (MRm + MRl), Shoestring Bay (SBu + SBm), and Ockway Bay (OBu). The concept is that for a scenario to achieve the restoration target for the whole of the Popponesset Bay System, it must first meet the target at the sentinel station and have nitrogen levels in the 3 main tributaries capable of supporting healthy infaunal animal communities (0.400 – 0.500 mgN/L). Station locations are shown in Figure 1.

The scenarios evaluated for the Towns of Mashpee, Barnstable and Sandwich for Popponesset Bay are listed below. The watershed nitrogen reduction was based upon a decision to reduce septic nitrogen loading by some % in some specific sub-watersheds, following Figure 2. Each of the first 2 modeling scenarios had a variant conducted in addition to the primary scenario designated 1 and 1+1 for the on-site wastewater removal scenario #1 and 2a and 2b in the on-site innovative septic treatment system scenario #2. The nitrogen loading rates associated with each of these scenarios are presented in Appendix A. Scenario #3 on natural attenuation in the Santuit River Cranberry Bogs resulted in an analytical modeling approach based upon the data developed for the scenario run and information gathered from other sources. The specific scenarios were as follows:

Scenario #1: Based upon Land-use N Loading and Linked Model in September 2004 Final Report. The total nitrogen loading from on-site septic system disposal of wastewater was removed (100% removal) from (MEP Watershed # -- Name, Figure 2):

- WS#6 – Upper Mashpee River, below Mashpee Wakeby Pond to Mashpee River Estuary
- WS#7 – Lower Mashpee River, estuarine reach of Mashpee River to mouth of river.
- WS#9 – Santuit River, below Santuit Pond to mouth at Shoestring Bay
- WS#16 – Cotuit Well #5, contributing area to well.
- WS#10 – Shoestring Bay Groundwater (direct seepage watershed to Shoestring Bay)

Other criteria: This modeling used existing conditions. The existing wastewater treatment facilities within the watershed were not altered. The nitrogen load from the septic systems in the watersheds set forward in Scenario #1 was discharged outside of the Popponesset Bay System (i.e. no return of treated effluent).

Variant #1+1: This variant on scenario #1 was conducted as a sensitivity analysis for the Local Project Team by the Technical Team. The sensitivity of the estuarine response to changes in watershed loading has been a focus of several discussions and the present effort provided a solid opportunity to address the issue. Scenario Variant #1+1 was identical to Scenario #1, but with the additional removal (100% removal of septic loading) from:

- WS# 15 – Quaker Run Wells, contributing area to wells.
- WS#8 – Quaker Run below Mashpee Wakeby Pond to mouth of Quaker Run in Bay

Note: These scenarios differ from those of the mtg (1/31/06) as per the Barker email of 2/3/06.

Results of Scenarios 1 and 1+1: Both Scenarios 1 and 1+1 met the threshold values at the sentinel station for eelgrass and within each of the 3 tributary sub-embayments relative to infaunal habitat. The additional removals in Scenario 1+1 had a demonstrable positive effect on lowering the nitrogen levels throughout the estuary, but particularly in Shoestring Bay (Table 1). The modeled present nitrogen distribution in the Popponesset Bay System and that under Scenarios 1 and 1+1 are also graphically presented in Figures 3-6.

Scenario #2: Based upon Land-use N Loading and the Linked Model in the September 2004 Final Report. Using the Build-Out Projection, all of the septic systems (present and future) will be fitted with denitrifying technologies, throughout the entire Popponesset Bay System Watershed. Since retrofitting of on-site septic systems with denitrifying units only removes a portion of the nitrogen from the treated effluent, a range of treatment efficiencies was used. The need for a defined N removal efficiency was discussed in detail at the 1/31/06 meeting. The Technical Team recommended a range of efficiency to constrain the range of operational effectiveness of I/A systems distributed watershed wide (i.e. the range of nitrogen removal expected across a watershed). Removal rates for these systems depend on a variety of factors including variations in influent nitrogen, system operation and maintenance, and the type of treatment technology. While the performance of systems can vary greatly, DEP determined that removal rates of 25% and 45% represent an appropriate range that brackets the expected performance under normal operating conditions and is suitable for this modeling exercise.

Run 1: nitrogen removals will be at a 25% reduction in N loading to the aquifer, based upon DEP's evaluation of the lower range of expected performance.

Run 2: nitrogen removals will be at a 45% reduction in N loading to the aquifer, based upon DEP's evaluation of the upper range of expected performance.

Results of Scenarios 2a and 2b: Both Scenarios failed to meet the threshold values at the sentinel station for eelgrass or within each of the 3 tributary sub-embayments relative to infaunal habitat. Even at the higher efficiency of operation (45%) the on-site denitrifying systems had only a small impact on attaining the target nitrogen levels within the estuary (Table 1). The modeled nitrogen distributions in the Popponesset Bay System under scenarios 2a and 2b are also graphically presented in Figures 7 and 8.

Table 1. Comparison of TN concentrations for present conditions, threshold loading, and four modeled loading scenarios for the Popponesset Bay system. Threshold concentrations are 0.380 mg/L TN for the eelgrass (primary), and between 0.400 and 0.500 mg/L TN for infauna (secondary). Scenarios 1 and 1+1N, which are based upon present watershed land-use, both meet threshold requirements at all sentinel station locations in the system. Scenarios 2a and 2b, which are based upon the land-use at build-out of the watershed, do not meet threshold requirements. All values are total nitrogen (mgN/L). The scenario outputs should be compared to their ability to meet the threshold N level, and scenarios 2a and 2b are not comparable to scenario 1 and 1+1N.

Sentinel sub-embayment	Habitat	Present	Threshold	Scenario 1	Scenario 1+1	Scenario 2a	Scenario 2b
Popponesset Bay - head	eelgrass	0.464	<0.380	0.369	0.355	0.478	0.440
Mashpee River - mid to lower	infauna	0.712	0.400-0.500	0.470	0.458	0.772	0.686
Shoestring Bay - upper to lower	infauna	0.631	0.400-0.500	0.443	0.403	0.653	0.574
Ockway Bay - upper	infauna	0.567	0.400-0.500	0.462	0.4449	0.588	0.539
Achieve Threshold? (Yes/No)				Yes	Yes	No	No

Scenario #3: Based upon Land-use N Loading and Linked Model in September 2004 Final Report for existing conditions. Three bog/ponds (Bogs A, B, C) within the Santuit Pond parcel were “converted” to fresh ponds to enhance natural attenuation. The 2 eastern bogs are presently “ponds” as they are permanently flooded. Deepening of the bogs and management as groundwater fed freshwater ponds was investigated as a mechanism to attenuate the nitrogen passing through them. Deepening was necessary to enhance their functioning as groundwater discharge sites, which would increase the area of watershed from which water and nitrogen would be drawn. It is important to note that this scenario is being used to help the municipalities evaluate the need for a more thorough feasibility study on enhanced N attenuation on this parcel.

An analytical modeling approach was followed in the evaluation of Scenario #3. First, the maximum depth that could be created in the ponds was determined (Table 2.). The groundwater depression rate, based upon the depth and pond surface area combined with the hydraulic gradient (0.001), porosity (0.3) and recharge rate (27.5 in/yr), was then used to determine the size of the upgradient contributing area (Figure 10). Based upon the area of contributing upland and the groundwater contours, the upland area and its existing land-uses were mapped. Based upon the “captured” land-uses, the value of the scenario as a potential nitrogen attenuation approach was determined.

Table 2. Maximum depths attainable in bogs (A-C), based upon an angle of repose for saturated sand of 20% (J. Ramsey ACRE).

Bog ID	Bog Area Acres	Max Depth Meters	Max Depth feet
Bog A	1.146	7.7	25
Bog B	0.467	4.5	15
Bog C	3.067	11.0	36

The contributing area analysis indicated a low rate of nitrogen capture from upland sources for Bogs A and B. This results from their small size and spatial relationship to the adjacent neighborhood. The largest bog, C, did capture water from the adjacent neighborhood, on the order of 13 developed parcels with a 27.5 ft deepening. Based on average water use in the MEP Popponesset Bay watershed and the lawn fertilization rates, a capture by Bog C of the nitrogen loading associated with the 4 houses in the "10 ft watershed" would equal 22 kg/y, 10 houses in the 20 ft watershed would equal 55 kg/yr and 13 houses in the 27.5 ft watershed would equal 72 kg/yr. Based upon a reduction of 50% from the ponds, attenuated loads would be 11, 28, and 36 kg/yr, respectively.

Based upon the relatively low amount of nitrogen attenuation projected from this initial analysis the Technical Team concluded that a larger area would be needed to capture a sufficient watershed nitrogen load to make the project worthwhile. As a result, the Technical Team concluded that providing for a flow through the bogs from the Santuit Pond to the Santuit River might provide a cost-effective mechanism to remove the relatively high nitrogen load discharging from Santuit Pond.

Scientists with the Coastal Systems Program at SMAST have been working with Three Bays Preservation Inc. (Lindsey Counsell) and the Town of Barnstable (John Jacobson) to determine:

- Flow rates and directions within the bog system (Figure 9)
- Nitrogen transfers between bogs A-H, within the bog system
- Nitrogen discharge from Santuit Pond to Santuit River (through the bogs and directly)

This effort resulted in biweekly field data collection from August 2005 through February 2006.

Analysis of the data from this collaborative effort indicated that during winter (2005-06), flow from Santuit Pond through the bog system was relatively low, ~5% of the flow to the Santuit River. The nitrogen load transported through the bogs was also relatively small and more importantly, the nitrogen attenuation rate of this transported nitrogen was negligible (Figure 12). A key evaluation of the present level of natural attenuation can be made by evaluating the data from Bog D (with the central pond in it). During November – February, the average nitrogen loading into this bog (SPB 7) and the nitrogen from Bog E (SPB 3a) to a common gathering point (SPB5a) showed no nitrogen loss (0.09 kgN/d + 0.13 kgN/d to SPB4, with measured at SPB4 = 0.22 kgN/d).

In contrast to the winter situation, the summer period (August – October) showed much higher flows within the bog system (~2000 m3/d) and associated nitrogen loads. During summer ~25% of the flow to the Santuit River at station SR-2 entered through the bog system (Figure 11). In addition, there was some attenuation of nitrogen during bog passage. Again, a key evaluation of the present level of natural attenuation can be made by evaluating the data from Bog D (with the central pond in it). During August – October, the average nitrogen loading into this bog (SPB 7) and the nitrogen from Bog E (SPB 3a) to a common gathering point (SPB5a) showed a removal of ~20% of the nitrogen load during transport (1.97 kgN/d + 0.09 kgN/d to SPB4, with measured at SPB4 = 1.62 kgN/d). This indicates that on the order of

~80 kg N/yr may be being attenuated by passage through the bog system, based upon 6 months of the year where attenuation processes appear to be active. This should be considered to be an large underestimate as only Bog D was considered. Including the other bog areas with flow, but where attenuation was not measured, almost certainly would increase the amount of nitrogen removed, as Bog D represents less than one-fifth of the total bog area (to the west of the River) and in the large view of the entire bog system, less than ~one tenth of the overall bog area. If attenuation rates in other flooded bog areas are only as those measured in Bog D, it is possible that the present rate of removal by the multiple bog units may be more than 2-3 fold higher (160-240 kg/yr). It should be noted that there is both surface water flow and groundwater fed bogs that are almost certainly intercepting nitrogen that were not included in this analysis. Most of these bogs could be restored as wetland/pond systems with higher nitrogen attenuation rates, due to greater water/sediment contact surfaces and times.

The present data suggest that high flows through the bog system during summer are resulting in attenuation of nitrogen from Santuit Pond to Santuit River. Since the flow through the bog system is not being managed to maximize river/bog interactions, it appears that nitrogen attenuation by the bog system can be enhanced over present conditions merely though better flow management. Additional increases in nitrogen attenuation would be likely during summer if the bogs were altered to increase retention time within each bog unit and contact with the bog sediments. Bog D, for example, is currently not flooded so nitrogen attenuation can occur only in the creeks/ditches and in the central small pond. An estimate of 40-50% attenuation of transported nitrogen appears supportable, given that at present the attenuation by only a single unmanaged bog, which is only partially in contact with the river water, is ~20% of the N that is transported through it.

At present nitrogen attenuation by the bogs to the west of the Santuit River appears to be conservatively >160 kgN/yr and most likely between 200-240 kg/yr, if other of the adjacent bog units are also removing some small amounts of nitrogen (based primarily on acreages). This rate of N removal translates to ~ 40-45 septic systems (based on 2.1 kg/N/yr per person x 2.54 persons per household in the watershed). Increasing the attenuation efficiency to 40-50% by optimizing flows and pond/wetland management could, would result in a conservative N removal of 320-400 kg N/yr. Higher rates of nitrogen removal are likely attainable if more of the available bog units in a gravity flow through system, with flooding to support natural wetland species or ponds (or both). If the bog being examined by Mosquito Control were reconnected to the downgradient bogs, the area would be significantly increased and a nitrogen removal of 400-600 kg N/yr could likely be attained. It should be noted that this range of attenuation is based upon scaling the measurements of nitrogen attenuation for bog D. To check this scaling, we also examined the amount of nitrogen load that would be removed if the nitrogen load through the bogs to the west of the Santuit River reached 40% and 50% removal on an annual basis. The measured total nitrogen discharge from Santuit Pond during summer (180d) is 1511 kg N, with 491 kgN entering through SPB-1 and 1021 kgN through SR1. If the same proportion of flow between the bogs (34%) and the River (66%) were maintained in winter the winter total nitrogen discharge from Santuit Pond (185d) is 2048 kg N, with 510 kgN entering through SPB-1 and 1538 kgN through SR1. A 40%-50% removal of N passing through the bogs from SPB-1 would equal 400-500 kgN/yr. Considering that this does not incorporate nitrogen entering through the bogs to the north (mosquito control bogs) or any increase in discharge, this estimate agrees quite well with the 400-600 kgN/yr estimate of potential removal.

In order to refine these estimates to develop a more quantitative evaluation of nitrogen removal under managed conditions, the specific acreages to be included and flow volumes need to be developed. The refined estimates can then be used to evaluate this nitrogen removal alternative as N management planning proceeds. Equally important, attenuation is during the critical summer months, magnifying the resulting positive effect on the downgradient estuary. As a result of these preliminary findings, the MEP Technical Team recommends that the Towns of Mashpee and Barnstable determine if the apparent level of attenuation under managed conditions is sufficient to support a decision for further analysis. Further analysis would include (1) a survey to determine the bogs that could be linked by flow, (2) the ability to flood or deepen the appropriate bogs to enhance nitrogen retention, and (3) a decision as to how much open water versus wetland could be accommodated per bog unit. Once these issues are addressed, the MEP Technical Team can provide a more quantitative answer as to the additional nitrogen attenuation that might be achieved.

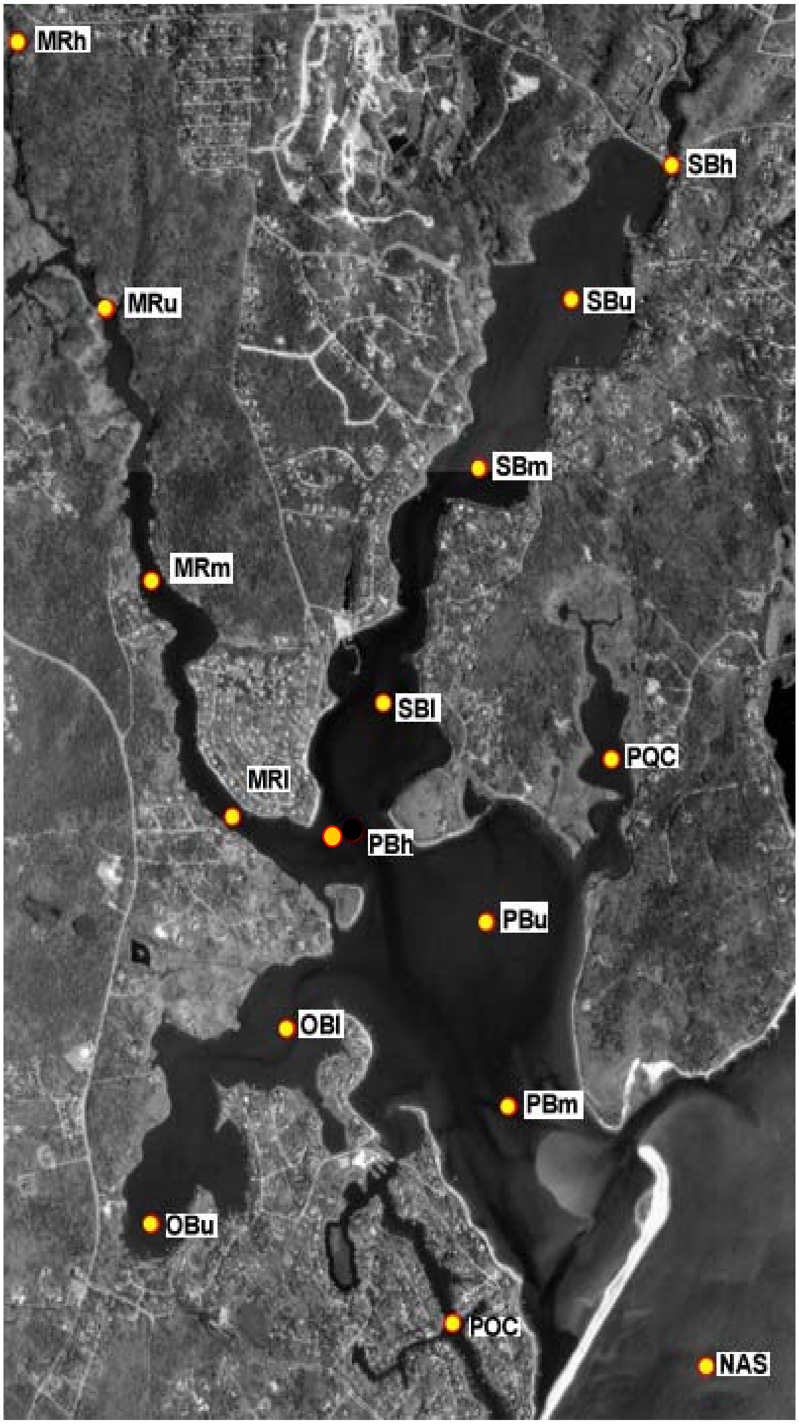

Figure 1. Location of estuarine water quality locations within the Popponesset Bay System. From the MEP Thresholds Report (2004). PBh is the sentinel station for eelgrass restoration.

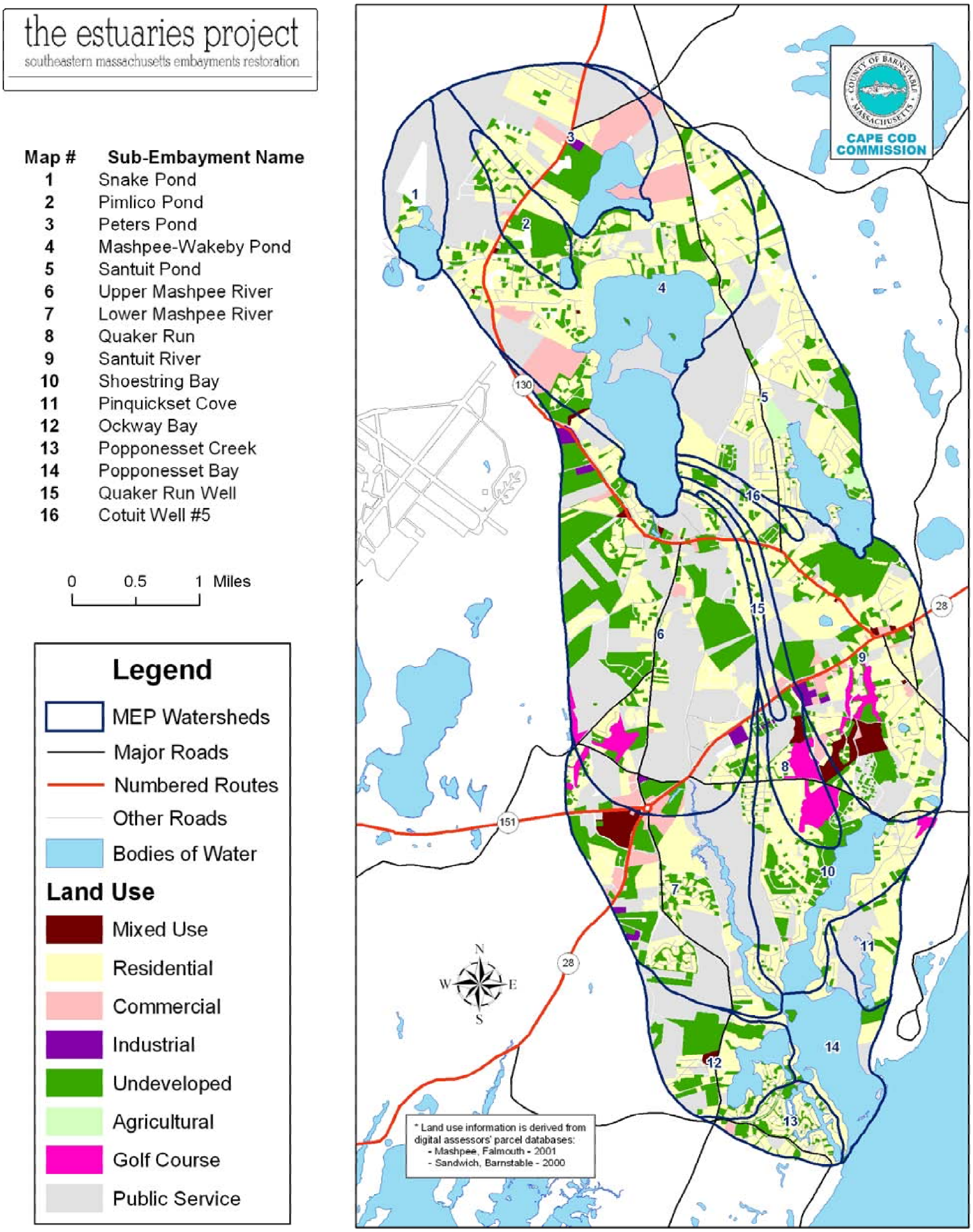

Figure 2. Land-use coverage in the Popponesset Bay watershed (Figure IV-1 in 2004 Tech Report). Watershed data encompasses portions of the Towns of Mashpee (west & north), Barnstable (east), & Sandwich (north), MA.

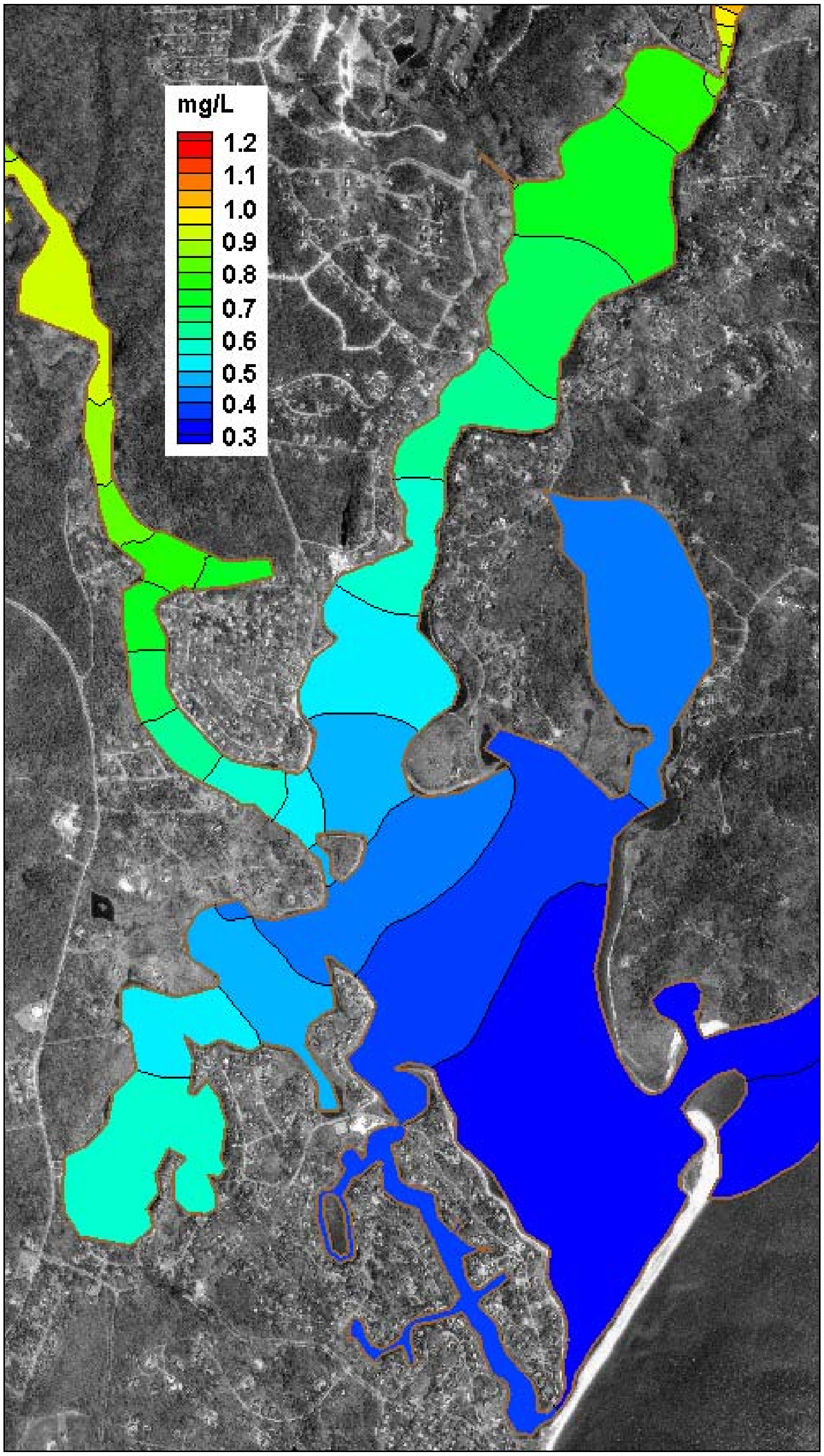

Figure 3. Contour plot of average TN concentrations for modeled **present** loading conditions in Popponesset Bay.

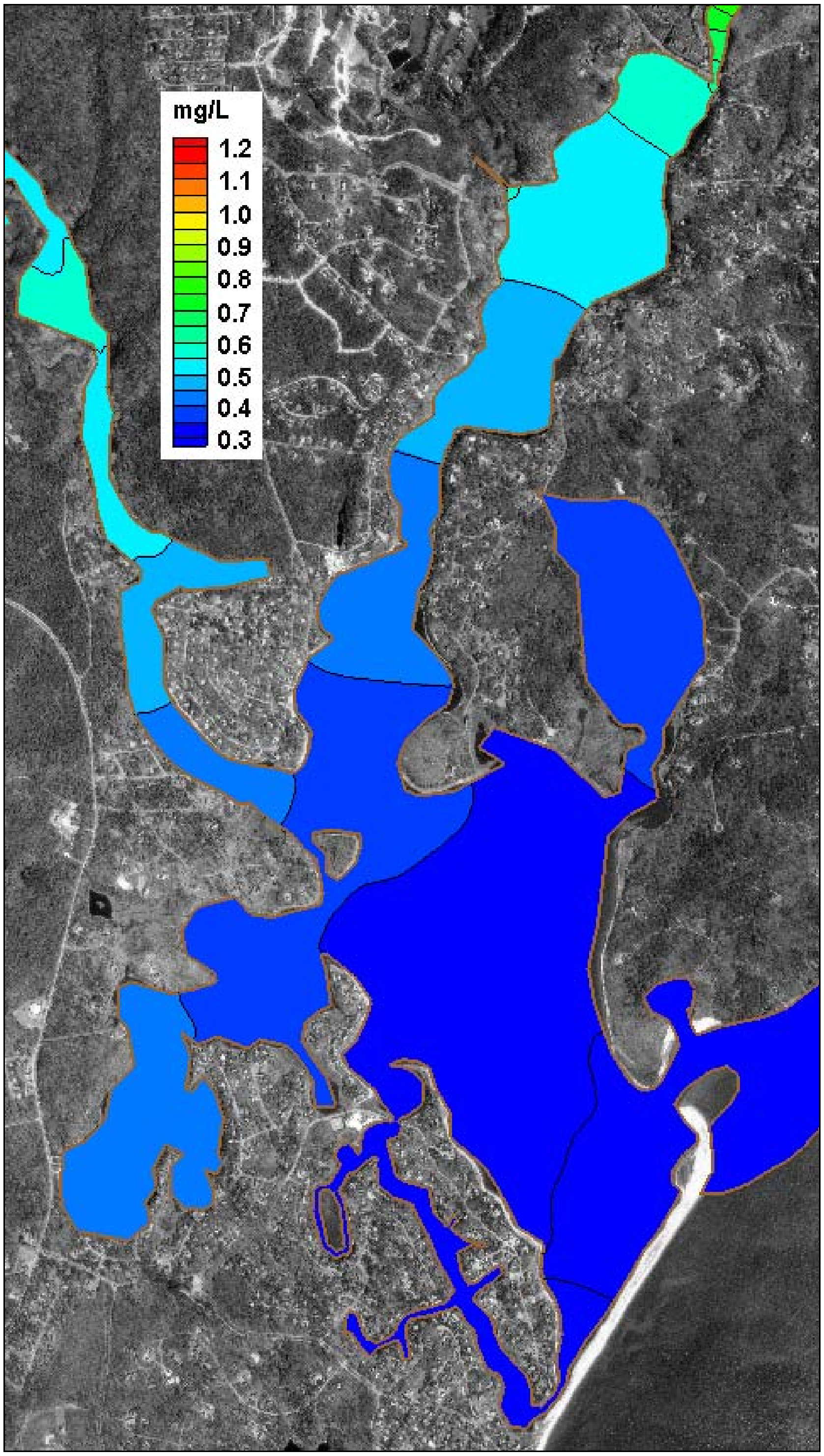

Figure 4. Contour plot of average TN concentrations for modeled **threshold** loading conditions in Popponesset Bay.

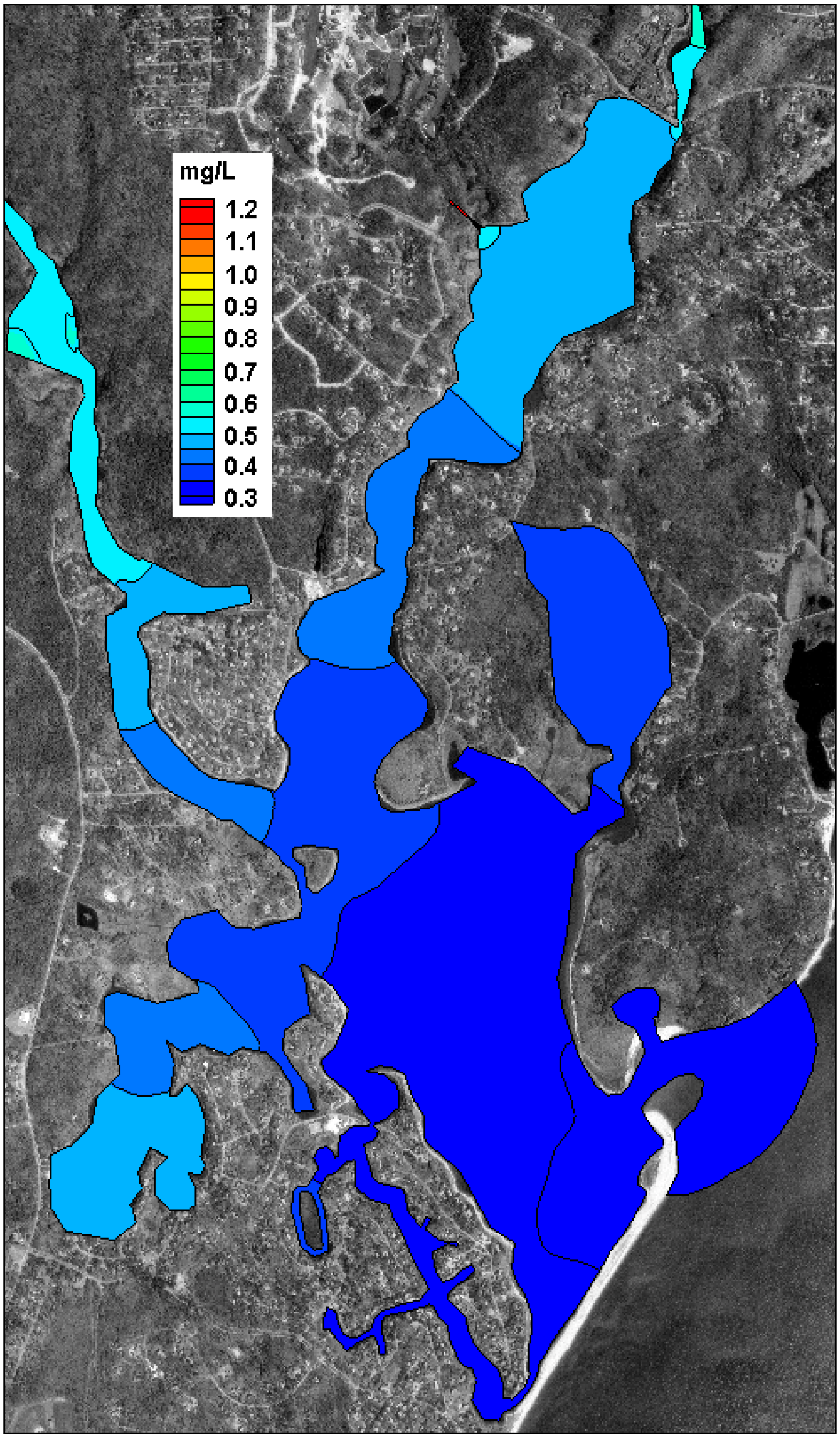

Figure 5. Contour plot of average TN concentrations for modeled **Scenario 1** loading conditions in Popponesset Bay.

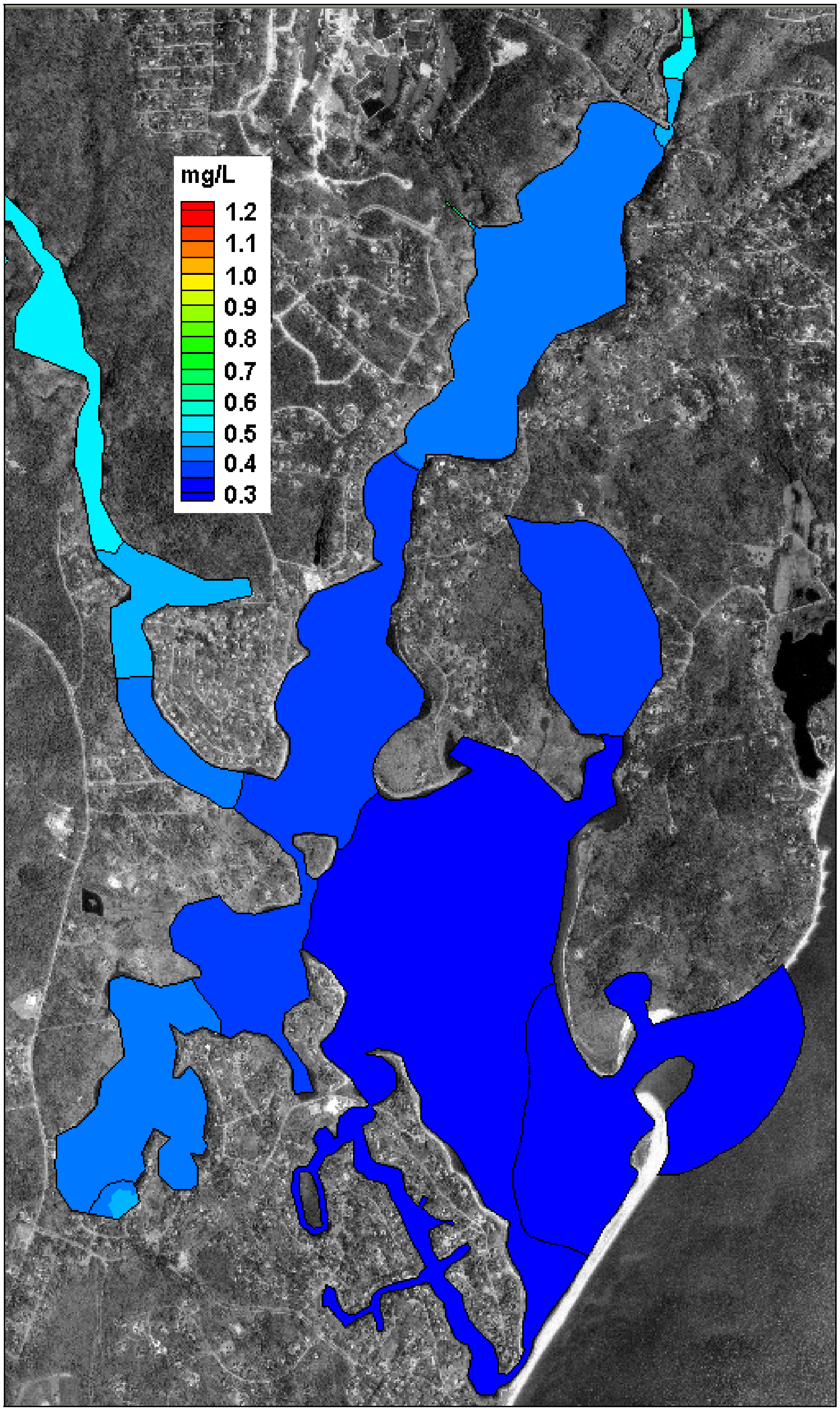

Figure 6. Contour plot of average TN concentrations for modeled **Scenario 1+1N** loading conditions in Popponesset Bay.

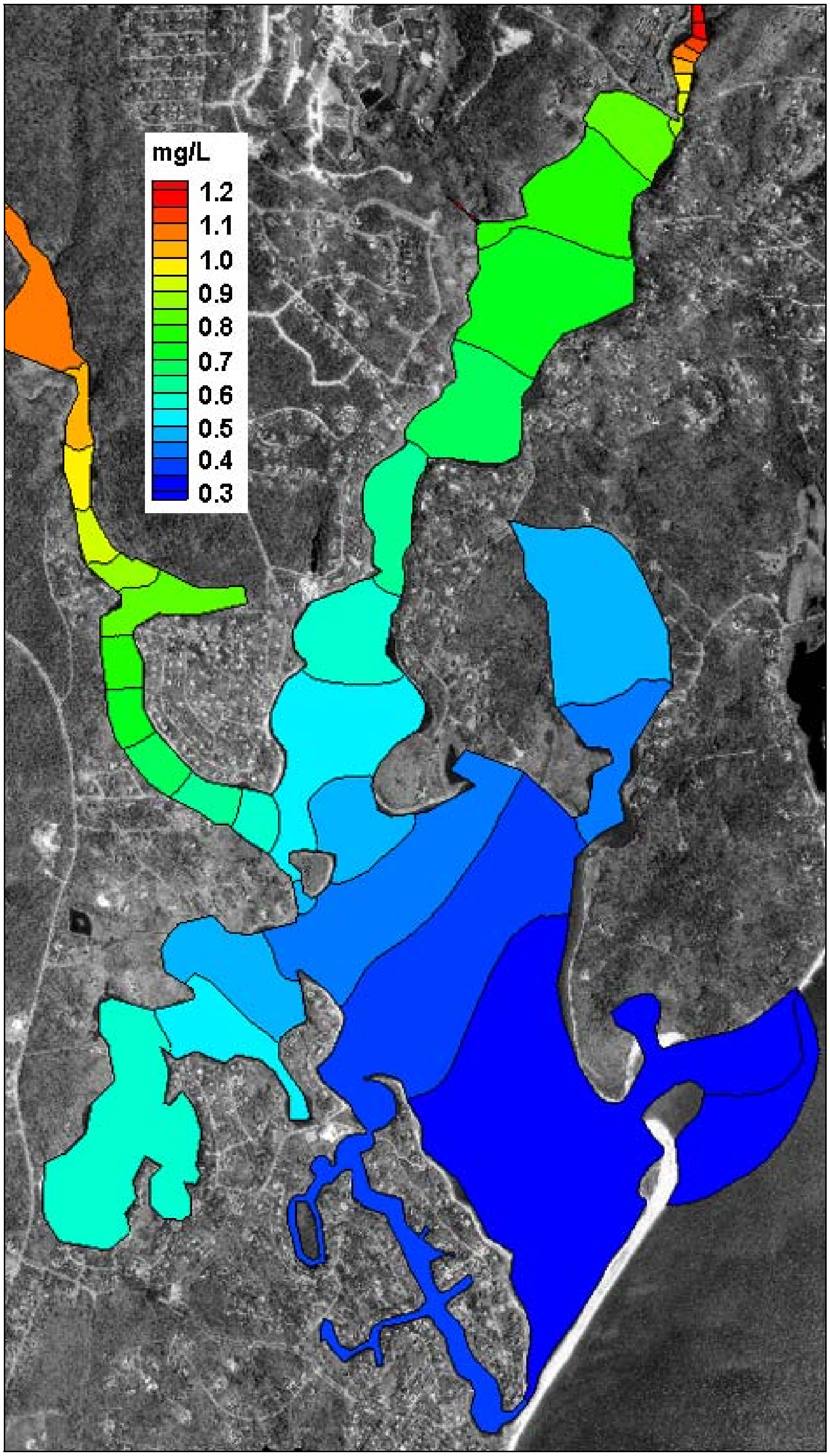

Figure 7. Contour plot of average TN concentrations for modeled Scenario 2A loading conditions in Popponesset Bay.

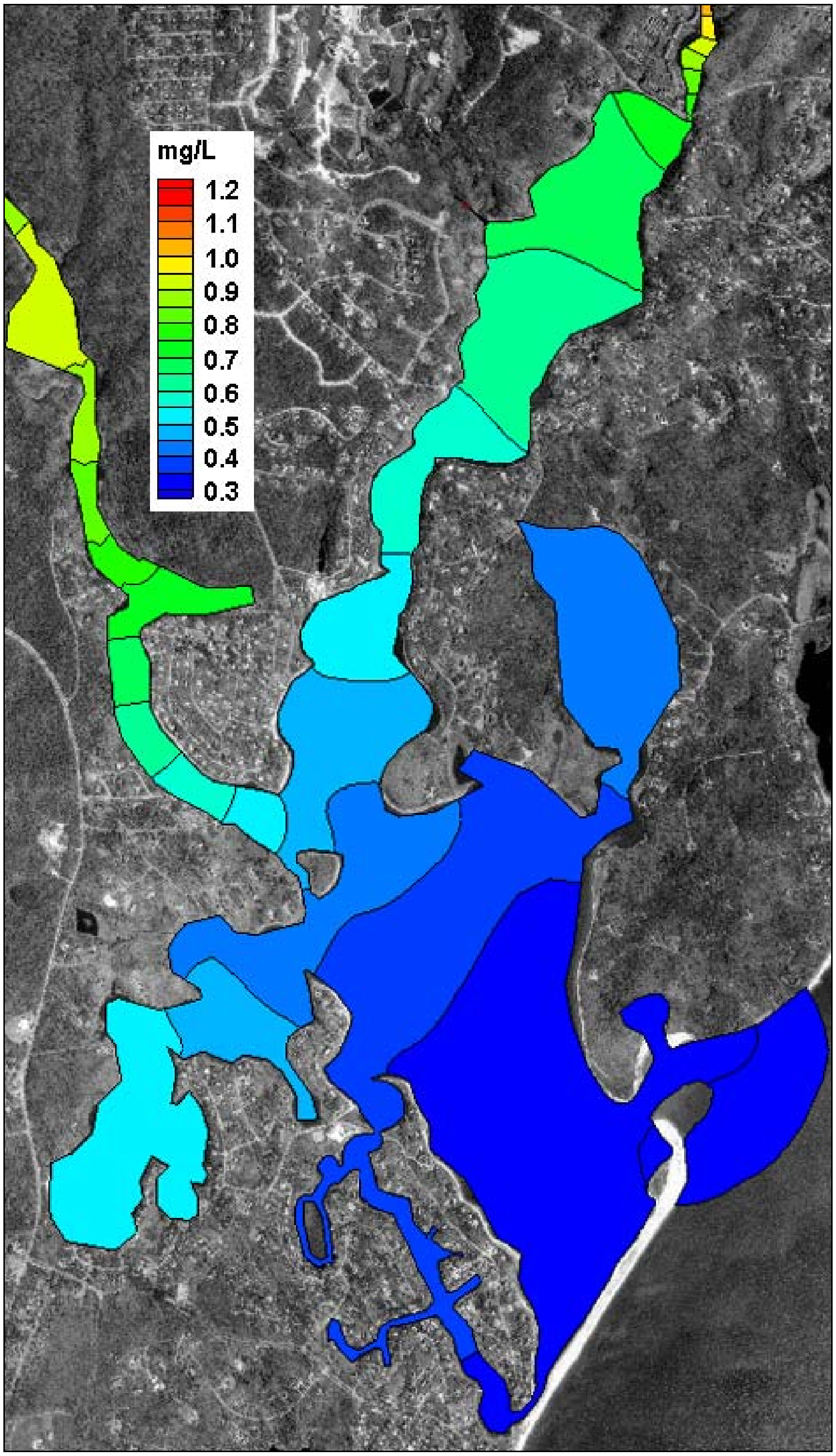

Figure 8. Contour plot of average TN concentrations for modeled **Scenario 2B** loading conditions in Popponesset Bay.

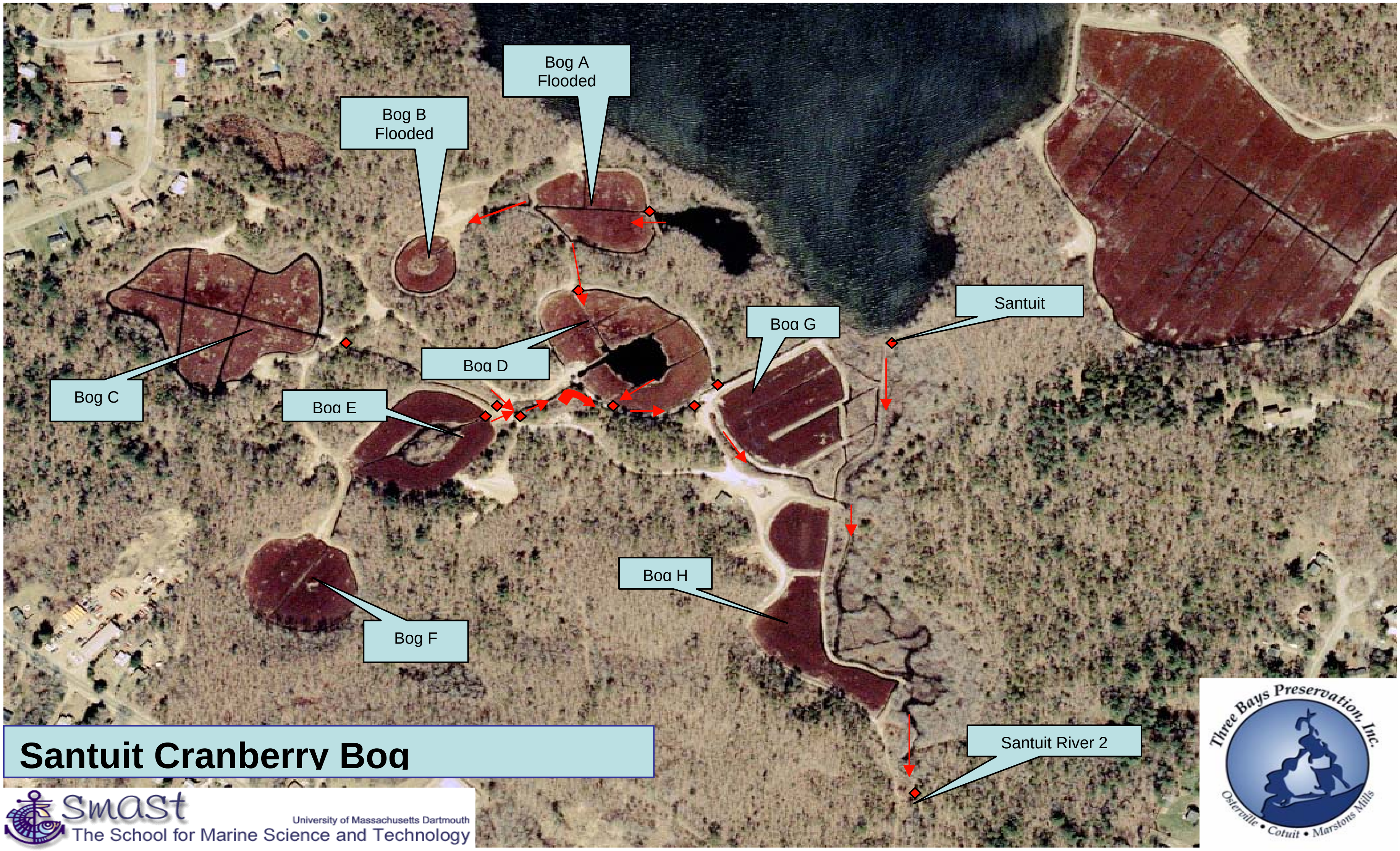

Figure 9. Location of Cranberry Bogs at the head of the Santuit River. Freshwater flows and nitrogen levels are being monitored by SMAST, Three Bays Preservation and the Town of Barnstable.

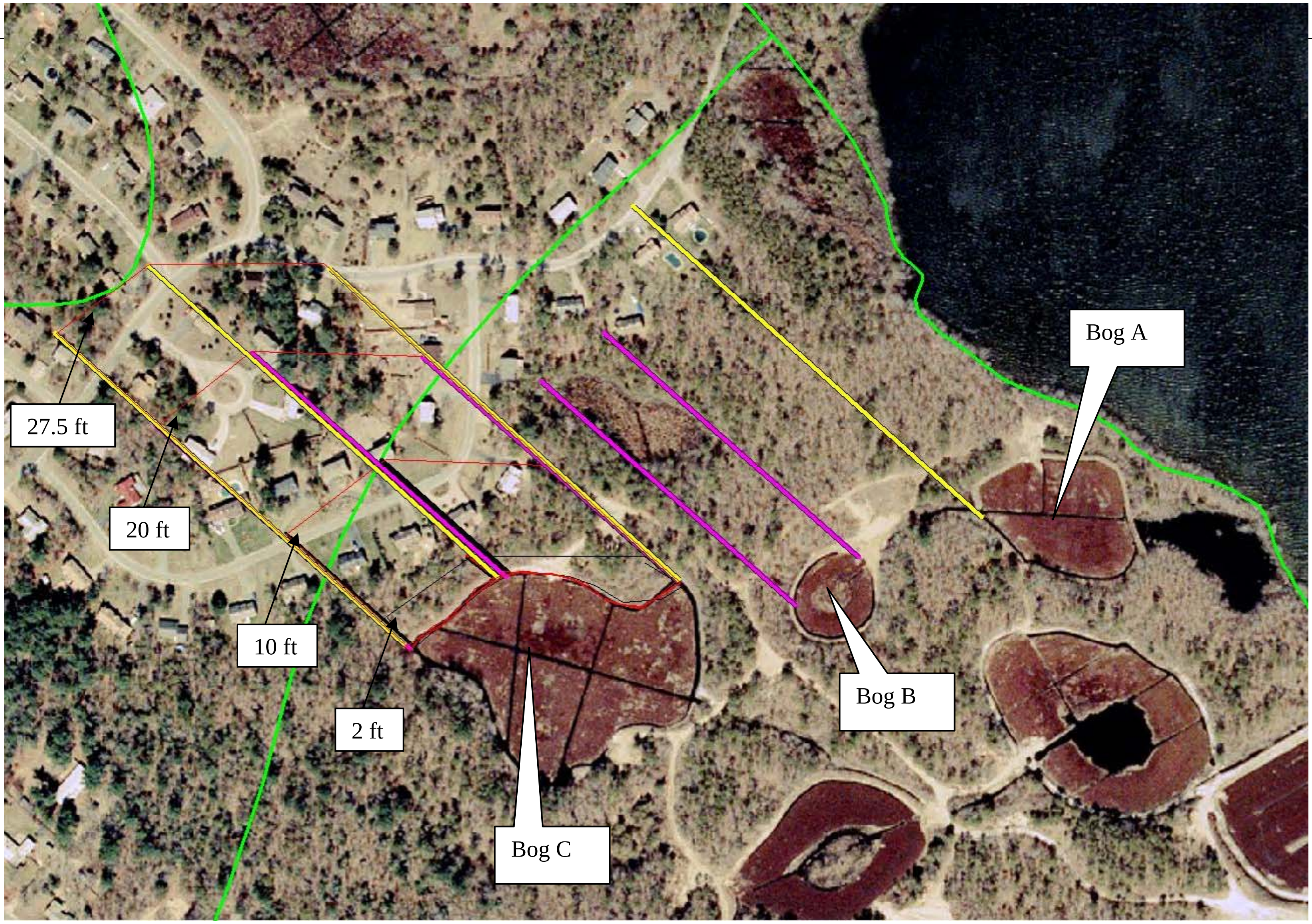

Figure 10. Potential watersheds to bogs deepened as groundwater fed freshwater ponds as per Table 2. The contours of 2, 10, 20 and 27.5 ft relate to different depths generated in Bog C.

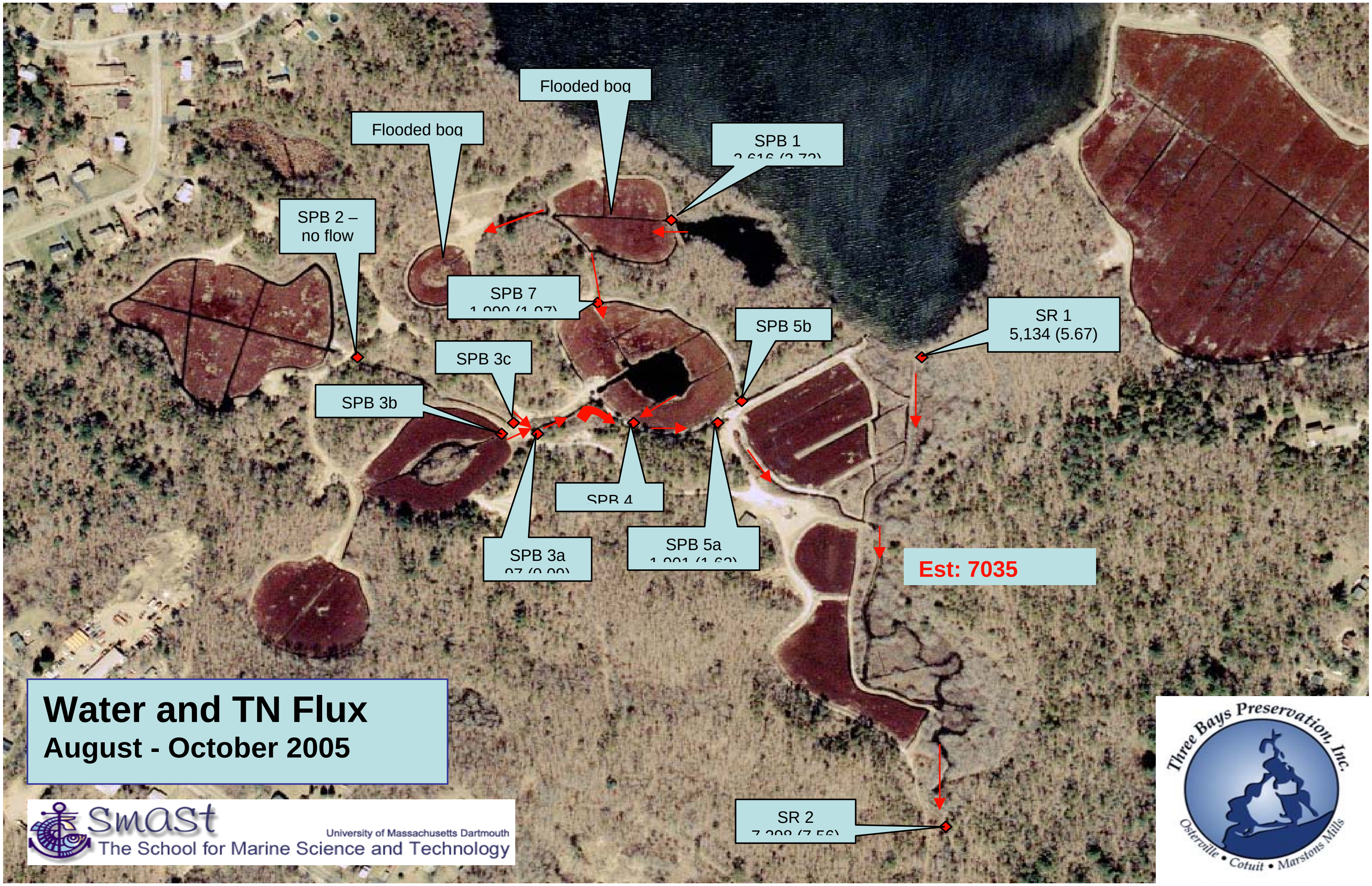

Figure 11. Average freshwater flows (m3/d) and TN loads (kg/d) from August – October within the Santuit Bog system. Courtesy of SMAST

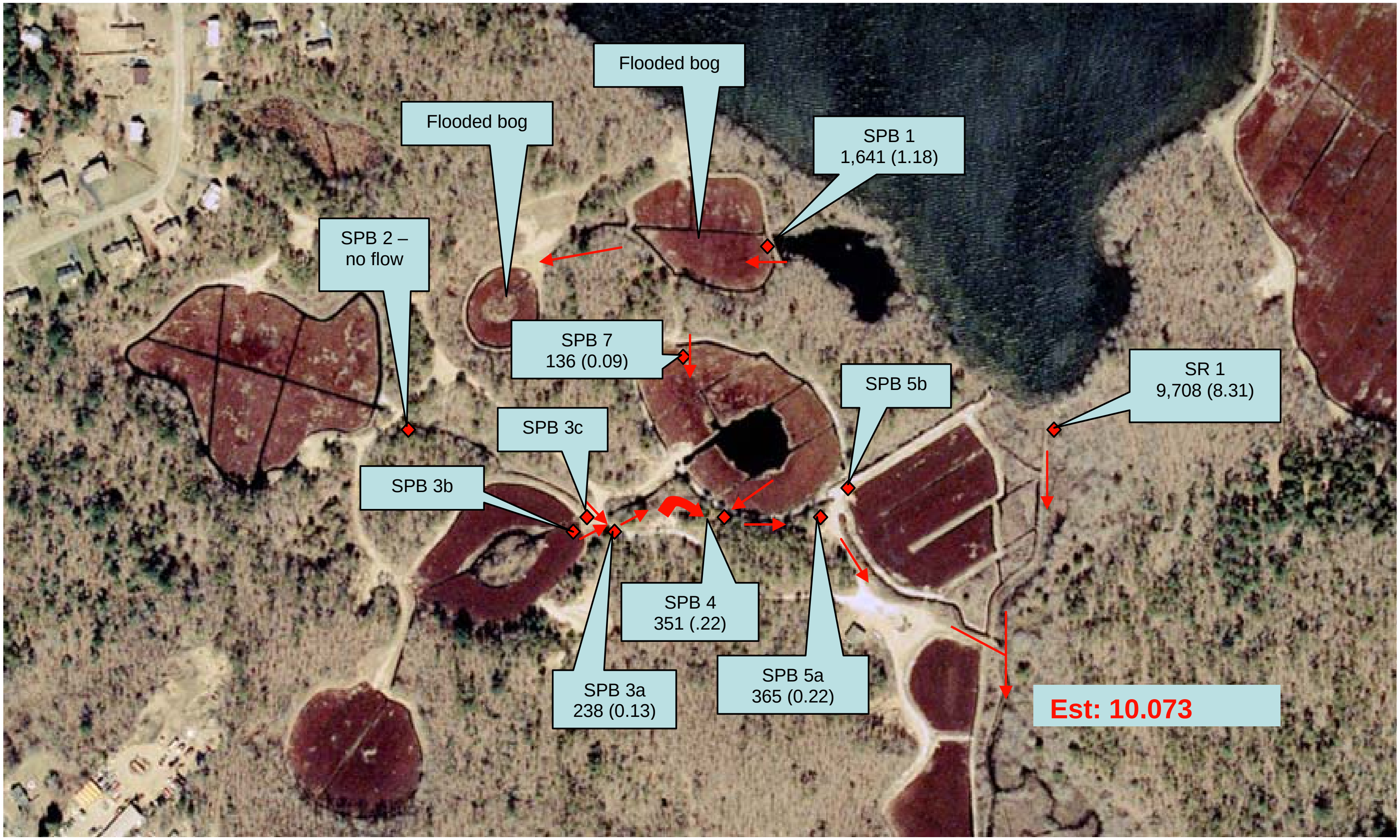

Figure 12. Average freshwater flows (m3/d) and TN loads (kg/d) from August – October within the Santuit Bog system. Courtesy of SMAST.

Appendix A

Nitrogen Loading Tables relative to
Scenarios 1, 1+1, 2a and 2b.

Table A-1. Sub-embayment and surface water loads used for total nitrogen modeling of the Popponesset Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These load represent **present loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Popponesset Bay	1.819	4.005	-5.039
Popponesset Creek	4.940	-	-0.639
Pinquickset Cove	0.764	0.290	-0.326
Ockway Bay - lower	-	-	-1.596
Ockway Bay - upper	3.151	1.093	3.372
Mashpee River	12.107	0.663	15.339
Shoestring Bay	9.208	2.233	-11.854
Surface Water Sources			
Mashpee River	21.888	-	-
Santuit River (Shoestring Bay)	15.584	-	-
Quaker Run River (Shoestring Bay)	5.984	-	-
TOTAL	**75.444**	**8.285**	**-0.743**

Table A-2. Sub-embayment and surface water loads used for total nitrogen modeling of the Popponesset Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These load represent **threshold loading conditions** for the listed sub-embayments. These loads represent the sub-watershed loading conditions for the scenario used in the MEP technical report to meet N threshold level.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Popponesset Bay	1.819	4.005	-4.915
Popponesset Creek	0.953	-	-0.624
Pinquickset Cove	0.764	0.290	-0.318
Ockway Bay - lower	-	-	-1.132
Ockway Bay - upper	0.757	1.093	2.249
Mashpee River	2.500	0.663	9.430
Shoestring Bay	2.260	2.233	-8.735
Surface Water Sources			
Mashpee River	13.668	-	-
Santuit River (Shoestring Bay)	11.474	-	-
Quaker Run River (Shoestring Bay)	5.983	-	-
TOTAL	**40.179**	**8.285**	**-4.044**

Table A-3. Sub-embayment and surface water loads used for total nitrogen modeling of the Popponesset Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These load represent **Scenario 1 loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Popponesset Bay	1.819	4.005	-4.940
Popponesset Creek	4.940	-	-0.627
Pinquickset Cove	0.764	0.290	-0.319
Ockway Bay - lower	-	-	-1.596
Ockway Bay - upper	3.151	1.093	3.372
Mashpee River	2.499	0.663	10.374
Shoestring Bay	2.258	2.233	-7.706
Surface Water Sources			
Mashpee River	13.318	-	-
Santuit River (Shoestring Bay)	7.510	-	-
Quaker Run River (Shoestring Bay)	5.984	-	-
TOTAL	**42.241**	**8.285**	**-1.441**

Table A-4. Sub-embayment and surface water loads used for total nitrogen modeling of the Popponesset Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These load represent **Scenario 1+1N loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Popponesset Bay	1.819	4.005	-4.927
Popponesset Creek	4.940	-	-0.625
Pinquickset Cove	0.764	0.290	-0.319
Ockway Bay - lower	-	-	-1.596
Ockway Bay - upper	3.151	1.093	3.372
Mashpee River	2.499	0.663	10.374
Shoestring Bay	2.258	2.233	-6.676
Surface Water Sources			
Mashpee River	13.318	-	-
Santuit River (Shoestring Bay)	7.510	-	-
Quaker Run River (Shoestring Bay)	1.605	-	-
TOTAL	**37.863**	**8.285**	**-0.397**

Table A-5. Sub-embayment and surface water loads used for total nitrogen modeling of the Popponesset Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These load represent **Scenario 2A loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Popponesset Bay	1.55	4.01	-5.05
Popponesset Creek	4.28	-	-0.64
Pinquickset Cove	0.79	0.29	-0.33
Ockway Bay - lower	-	-	-1.65
Ockway Bay - upper	3.44	1.09	3.51
Mashpee River	14.27	0.66	16.17
Shoestring Bay	7.92	2.23	-11.06
Surface Water Sources			
Mashpee River	25.45	-	-
Santuit River (Shoestring Bay)	16.67	-	-
Quaker Run River (Shoestring Bay)	5.42	-	-
TOTAL	**79.79**	**8.28**	**0.95**

Table A-6. Sub-embayment and surface water loads used for total nitrogen modeling of the Popponesset Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These load represent **Scenario 2B loading conditions** for the listed sub-embayments.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux (kg/day)
Popponesset Bay	1.21	4.01	-4.28
Popponesset Creek	3.43	-	-0.54
Pinquickset Cove	0.65	0.29	-0.28
Ockway Bay - lower	-	-	-1.48
Ockway Bay - upper	2.82	1.09	3.14
Mashpee River	11.59	0.66	14.18
Shoestring Bay	6.45	2.23	-9.26
Surface Water Sources			
Mashpee River	21.56	-	-
Santuit River (Shoestring Bay)	13.63	-	-
Quaker Run River (Shoestring Bay)	4.47	-	-
TOTAL	**65.82**	**8.28**	**1.47**

Table A-7. Comparison of sub-embayment watershed loads used for modeling of present, threshold and scenario loading conditions of the Popponesset Bay system. Loads do not include direct atmospheric deposition (to embayment surface) or benthic flux. "Threshold" load is from the scenario used in the MEP technical report to meet the N threshold levels in the Bay.

sub-embayment	present load (kg/day)	Threshold (kg/day)	threshold % change	Scenario 1 (kg/day)	Scenario 1 % change	Scenario 1+1N (kg/day)	Scenario 1+1N % change	Scenario 2A (kg/day)	Scenario 2A % change	Scenario 2B (kg/day)	Scenario 2B % change
Popponesset Bay	1.819	1.819	0.0%	1.819	0.0%	1.819	0.0%	1.551	-14.8%	1.211	-33.4%
Popponesset Creek	4.940	0.953	-80.7%	4.940	0.0%	4.940	0.0%	4.277	-13.4%	3.427	-30.6%
Pinquickset Cove	0.764	0.764	0.0%	0.764	0.0%	0.764	0.0%	0.795	+3.9%	0.647	-15.4%
Ockway Bay	3.151	0.757	-76.0%	3.151	0.0%	3.151	0.0%	3.441	+9.2%	2.822	-10.4%
Mashpee River	12.107	2.500	-79.4%	2.499	-79.4%	2.499	-79.4%	14.271	+17.9%	11.592	-4.3%
Shoestring Bay	9.208	2.260	-75.5%	2.258	-75.5%	2.258	-75.5%	7.918	-14.0%	6.455	-29.9%
Surface Water Sources											
Mashpee River	21.888	13.668	-37.6%	13.318	-39.2%	13.318	-39.2%	25.447	+16.3%	21.562	-1.5%
Santuit River	15.584	11.474	-26.4%	7.510	-51.8%	7.510	-51.8%	16.671	+7.0%	13.630	-12.5%
Quaker Run River	5.984	5.983	0.0%	5.984	0.0%	1.605	-73.2%	5.416	-9.5%	4.474	-25.2%
TOTAL	75.444	40.179	-46.7%	42.241	-44.0%	37.863	-49.8%	79.786	+5.8%	65.819	-12.8%

Table A-8. Comparison of sub-embayment septic loads used for modeling of present, threshold and scenario loading conditions of the Popponesset System. "Threshold" load is the scenario used in the MEP Tech Rpt to meet the N threshold levels in the Bay.

sub-embayment	present load (kg/day)	Threshold (kg/day)	threshold % change	Scenario 1 (kg/day)	Scenario 1 % change	Scenario 1+1N (kg/day)	Scenario 1+1N % change	Scenario 2A (kg/day)	Scenario 2A % change	Scenario 2B (kg/day)	Scenario 2B % change
Popponesset Bay	1.578	1.578	0.0%	1.578	0.0%	1.578	0.0%	1.310	-17.0%	0.970	-38.5%
Popponesset Creek	3.986	0.000	-100.0%	3.986	0.0%	3.986	0.0%	3.323	-16.6%	2.474	-37.9%
Pinquickset Cove	0.576	0.576	0.0%	0.576	0.0%	0.576	0.0%	0.606	+5.2%	0.458	-20.5%
Ockway Bay	2.394	0.000	-100.0%	2.394	0.0%	2.394	0.0%	2.684	+12.1%	2.065	-13.7%
Mashpee River	9.607	0.000	-100.0%	0.000	-100.0%	0.000	-100.0%	11.772	+22.5%	9.092	-5.4%
Shoestring Bay	6.948	0.000	-100.0%	0.000	-100.0%	0.000	-100.0%	5.657	-18.6%	4.194	-39.6%
Surface Water Sources											
Mashpee River	14.008	5.789	-58.7%	5.438	-61.2%	5.438	-61.2%	17.567	+25.4%	13.682	-2.3%
Santuit River	11.688	7.578	-35.2%	3.614	-69.1%	3.614	-69.1%	12.775	+9.3%	9.734	-16.7%
Quaker Run River	4.367	4.367	0.0%	4.367	0.0%	0.000	-100.0%	3.800	-13.0%	2.858	-34.6%
TOTAL	55.152	19.888	-63.9%	21.949	-60.2%	17.571	-68.1%	59.495	+7.9%	45.528	-17.5%

Appendix B

Response to Comments from Popponesset Bay Local Project Team

<u>These comments use the term Tech Report (TR) and Tech Memo (March 31 2006 SMAST memo to Popponesset Bay Local Pilot Project Team) to distinguish between the 2 documents.</u>

QUESTIONS ON MODELING PROCESS AND RESULTS

Responses follow the questions and are in italics

Scenarios 1 and 2:

Was modeling done with the new septic loading co-efficient and other adjustments made since the original Tech Report in 2004? If yes, please explain briefly the septic co-efficient and whether it differs materially from the original assumptions. If no, please clarify the septic N concentrations used for present conditions and buildout in the Tech Report.

The septic loading coefficient and the values used in the MEP Popponesset Technical Report result in exactly the same derived N loads. The only difference is in how the terms are arranged. The septic loading coefficient obviates the need for a specific septic N concentration and instead derives from the per capita septic nitrogen load to groundwater. This was explained in detail at the meeting If further explanation is required, DEP can provide it at a meeting or the Team can request a presentation by the Technical Team.

Scenario 1 and 1+1:

Scenario 1 and 1+1 results in Table 1 are shown as single values, while 2 of the 3 infauna values in the TR scenario are ranges. What is the range of the Table 3 infauna values?

As was discussed in the meeting, the threshold infauna N levels are ranges, 0.400-0.500 mgN/L (see table 1). Water column values falling within the range would meet the criteria.

Scenario 1+1: since Scenario 1 alone met the threshold conditions, this scenario was not needed to achieve thresholds but to test the model's sensitivity. What conclusions can be drawn about model sensitivity based on modeling results, and what are the implications for the estuary?

The Local Pilots Team needs to compare the load reduction to the water column N concentration change. It was interesting that while the Quaker Run N reduction (1+1) had the greatest affect on Shoestring Bay, it also lowered N levels System-wide.

There are different "present" and threshold septic loads in the Tech Report (Table A-8), vs. the Final Popponesset Bay TMDL report Table B-1), for the Mashpee River. The TMDL report uses 16.85 kg/day present and 8.63 threshold numbers, while the Tech Report says 14.008 and 5.789. Why?

Several data items can be addressed here:

(1) the Technical Report of September 2004 had some minor revisions to the upper Mashpee River N loading. All other loads and factors are unchanged. The MEP produces living models that are

updated periodically in response to new information. At the point the revisions become significant, a new Technical Report or a Technical Memo is produced.

(2) The TMDL report that was referred to appears to be a Draft and there is a newly available Final (at the meeting someone indicated a date of April 10, 2006).

(3) The present septic loading to the head of the Mashpee River Estuary (i.e. from watersheds inland, not the sub-watershed to the estuarine reach) is 14.008 kg N/yr and in the one threshold scenario in the Technical Report, was 5.789 kg N/yr. These are the values used in the Technical Memorandum as well (see table A-8).

The subembayment watershed loads in Column 2, Table 5 in the TMDL report were used to develop Mashpee's alternate nitrogen allocation model. What are the results of Scenario 1 and 1+1 in this format?

DEP can describe in a meeting. This is outside of the Technical Team's purview.

Mashpee River septic loads: These scenarios assume 100% septic removal in Subwatershed # 7 and 8 (Upper and Lower Mashpee River), but no removal from subwatersheds 1-4. Even accounting for natural attenuation of the loads from subwatersheds 1-4, the results in Table A7 and A8 seem too high when you compare them with results in the Tech Report Rainbow Table.

Ed Baker gets a cheer for this comment. Table A-7 and A-8 did not properly show the septic N loading from the upper watershed in Scenarios 1 and 1+1, as he indicated in the meeting (0.8 rather than 5.8). These tables have been revised as has table 1. There is no change in the conclusions. Note that all other scenario N loads have also been checked and are unchanged.

Scenarios 2a and b:

The underlying question posed by the Local Team is "what difference would it make at buildout if we required every septic system to be an I/A?" To answer this, results of Scenarios 2a and b need to be compared to the build-out scenarios run in the TR (pp 98-99). One option would be to show in this Tech Memo the threshold values for the TR build-out scenario; pp -98-99 in the Tech Report only show kg/day and % changes from present load. Another option would be to include in Tables A5- A8 the subwatershed loadings for buildout in the TR.

The answer to the question posed by the Local Team is that the embayment would not be restored, but would continue to be impaired for infauna in the Mashpee River, Shoestring Bay and Ockway Bay and eelgrass would not be restored. In fact, at build-out with full I/A installation, the system would look much like it does today. This can be seen by comparing the water column N levels in each sub-embayment in the Scenario 2a and 2b columns with the "Present" column. As can be readily seen, the values are much the same indicating that the habitat quality would be much the same.

Scenario 3:

P 4, 2nd paragraph, last line: This prediction of attenuation is based on pond attenuation in Popponesset Bay. Are there factors in bogs converted to ponds vs. long-standing ponds that could change this 50% attenuation rate?

Yes, the prediction is based upon measured pond/stream attenuation in various MEP projects. The present DEP contract on natural attenuation should detail the factors involved.

P 4, Last line: Memo reports b*imonthly* data collection, which would be every 2 months. How many sampling events were done, and from what range of dates? From Aug 12 – Nov 16, sampling was almost weekly acc. to 11/18/05 email from Dale. Chemicals analyzed and the full set of analytical results should be included in an appendix, or at least a reference to where they can be found. There is also a map from Three Bays of the sampling sites to include in an appendix.

(1) Biweekly.
(2) The summary data is presented. As indicated the study is still underway and is part of an effort by SMAST with the Town of Barnstable and Three Bays Preservation. The technical report from this effort will be available through these organizations when the study is complete.

P 5, first sentence: What is the amount of winter flow to the Santuit, that matches the ~5%?

In figure 12, the outflow from the bogs is ~400 m3/d compared to the river at ~10,000 m3/d.

P 5, 2nd paragraph, 5th sentence: "During August – October, the average nitrogen loading into this bog (SPB 7) and the nitrogen from Bog E (SPB 3a) to a common gathering point (SPB5a) showed a removal of ~20% of the nitrogen load during transport (1.97 kg N/d + 0.09 kg N/d to SPB4, with measured at SPB4 = 1.62 kg N/d)." How many data points are included in this calculation? Range? Std deviation?

The critical point is that in 9 summer samplings, 8 showed significant uptake and 1 showed zero uptake. The average uptake was ~0.4 kgN/d. This represented a removal of ~20% of the load to SPB-5a from SPB-7 + 3a. More sampling is being conducted by the research team.

P 5, 2nd paragraph, last sentence: *"It is possible that the rate of removal may be more than 2 fold higher."* AND P 5, 3rd paragraph, last sentence: *"An estimate of ~40-50% attenuation of transported nitrogen appears supportable, given that the present attenuation by only a single bog is ~20% and that flows are not being tuned for nitrogen management."*

- More than 1 bog appears to be included: some flows seem to be coming through Bog E. Also, isn't there some groundwater attenuation, given the interconnected flows?

  Yes, but you can't determine the attenuation from these systems with the available data. That other bogs are involved is why we conclude that more than 160 kgN/yr are likely being attenuated.

- What are the factors that support the estimate of 40-50% attenuation? Are there factors that would not support it?

  The point is that the present situation is not ideal and that management should increase the rate of removal to what is more normally seen, 40%-50%.

- What would better-tuned flow management include? Continuous flooding? Maximized flow through the bogs? Other?

That is for the next phase of the study to determine.

P 5, 4th paragraph, 2nd sentence: *"… 3) a decision as to how much open water versus wetland could be accommodated per bog unit"* What does this mean? Is this a regulatory or scientific decision?

The Local Team should determine the regulatory boundaries to open water versus wetland area, only then can alternatives be realistically investigated.

What additional monitoring, if any, would be recommended as part of a Town decision to pursue a more quantitative estimate of potential nitrogen attention in the Santuit Bogs?

The bog investigation should continue and expand into a full feasibility study.

What unintended problems could be created by tuning the flow of pond water through the bogs, and how could they be resolved? For example, the herring fishery has been damaged in the past with the entrapment and ultimate death of herring fry in a Santuit Pond Bog. A significant temperature rise may occur in diverted pond water before it reaches the river. If the impacts of solar radiation cause minor rises in stream temperature, the brook trout population may be endangered. There is also the potential for an increase in mosquito habitat. Are there design parameters for wetlands that would preclude this as a problem?

The temperature rise would not be significantly higher than at present, if the proportion of direct flow to the River and flow via the bogs is kept under present conditions. Mosquito habitat should decline.

ADDITIONAL POINTS FOR DISCUSSION ON APRIL 26TH

Scenario 1 and 1+1:

Does it make sense for towns to look for N reductions beyond those needed in order to come in right at the threshold values? At the levels shown in Scenario 1 and 1+1, could towns expect any noticeable benefit to the estuary, or would it be simply add to the Margin of Safety?

Margin of safety

Scenario 3:

To clarify the small impact of this scenario: 36 Kg/yr = .1 kg/dy, or 2-3% of the 4 kg/dy reduction in current loadings needed to reach the TR threshold numbers for Santuit River. (Tables A-1 and A-2 on p 19 of memo: 15.584 kg/dy-11.474 kg/dy = ~4 kg/dy reduction needed.) Using buildout loadings would result in smaller percentages.

Scale of N attenuation by altering flow is also small: 80 Kg/yr = 5.5% of the 4 kg/dy reduction in current loading needed to reach the TR threshold numbers for Santuit River. (Tables A-1 and A-2 on p 19 of memo: 15.584 kg/dy-11.474 kg/dy = ~4 kg/dy reduction needed.). 200 kg/yr = 15% of flow reductions needed in Santuit River watershed to meet TR thresholds. Percentages of total Pop Bay reductions and at buildout would be smaller.

Creating ponds has been discussed as one of the most promising steps to take to enhance natural attenuation. Why is that not true in this case? What are the implications of these results for other bog areas in Pop Bay?

Site-by-site considerations.

Santuit Pond has eutrophication problems due to phosphorus, which is not addressed in MEP work and the nitrogen TMDLs. Does it make sense to address both the nitrogen and phosphorus problems simultaneously (likely through sewering)?

It is important to determine the proper P management direction and not just assume that sewers will "fix" the problem. This is important information to have as soon as possible.

EDITING COMMENTS

P 1, paragraph 1, second sentence: "Municipal Committee Meeting" should be Local Pilot Project Team. "Municipal Committee" and "Committee" throughout memo should be changed to Local Pilot Project Team or Project Team.

Changed

PP 2-3, Scenario 1 and 1+1:

In evaluating these results, a key comparison is with the results in the Tech Report (TR) scenario that meets the thresholds (p 123): Scenarios 1 and 1+1 result in TN, eelgrass and infaunal numbers below the TR scenario. The TR numbers should be included in Table 1.

The values are available to the Local Team.

P 3, Table 1: Columns labels are confusing. Suggest two changes:
Second column: Threshold Parameter or Threshold Measure (instead of threshold)
Third column: Threshold Values (instead of threshold)

Clarification added.

P 3, Table 1: Readers need to see the TR and Tech Memo results side by side for scenarios 2 and 2a. This could be done in an expanded Table 1 or a separate table. Separating the results of Scenarios 1 and 2 applies also to Tables A-7 and A 8.

P 4, 1st full paragraph, last sentence: should "exiting" be "existing"?

Typo corrected.

P 4, Table 2: data for Bog A and C are transposed.

Typo corrected.

P 5, 1st paragraph, last sentence: *"During November – February, the average nitrogen loading into this bog (SPB 7) and the nitrogen from Bog E (SPB 3a) to a common gathering point (SPB5a) showed no nitrogen loss (0.09 kg N/d + 0.13 kg N/d to SPB4, with measured at SPB4 = 0.22 kg N/d)."* Is there a word missing in this phrase?

No.

P 19, Table A-2 heading: I assume "threshold loading conditions" refers to the TR scenario that meets the thresholds? Description as is implies that these values are fixed, rather than changeable depending on the scenario chosen. Should read something like: "These loads represent the subwatershed loading conditions for the scenario used in the Technical Report to meet nitrogen and infauna thresholds."
Text added.

P 22, Table A-7: Change headings in columns 3 and 4 to indicate this is the TR scenario.
Text added.

APPENDIX L

SMAST University of Massachusetts Dartmouth
The School for Marine Science and Technology

************************ Technical Memorandum ***************************

To: Tom Fudala, Mashpee Sewer Commission
Jim Hanks, Mashpee Waterways Commission

From: Brian Howes, Director Coastal Systems Program
Roland Samimy, Coastal Systems Program
John Ramsey, Applied Coastal Research & Engineering, Inc.
Sean Kelley, Applied Coastal Research & Engineering, Inc.
Ed Eichner, Cape Cod Commission

RE: Scenario Run of Popponesset Bay MEP Linked Model

Date: April 6, 2007

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The present Technical Memorandum details the results of 1 Scenario Run of the MEP Linked Watershed-Embayment Model developed for the Popponesset Bay System as described in the MassDEP/SMAST MEP Nitrogen Threshold Report for Popponesset Bay[1]. The Scenarios focus on determining whether a constant reduction of 49.2% homogeneously applied across the entire watershed will be sufficient to meet the nitrogen threshold at the sentinel station at the head of the main basin. Meeting the nitrogen threshold at the sentinel station is needed to restore the currently impaired eelgrass and benthic infaunal habitats throughout this estuarine system.

At present, historic eelgrass and benthic animal habitat within much of the Popponesset Bay Estuary is significantly impaired owing to watershed nitrogen inputs that exceed this estuary's assimilative capacity, resulting in eutrophic conditions. As part of nitrogen management planning the Towns of Mashpee, Barnstable and Sandwich, with the MassDEP Pilots Project have worked with SMAST in the use of the MEP Linked Model for Popponesset Bay. The present effort is part of the third round of scenario runs for the Popponesset Bay System.

The present effort is at the request of the Mashpee Sewer Commission, in order to provide additional information to MassDEP, municipal officials, private citizens and environmental groups to support decisions regarding the nitrogen management planning and load allocation decisions related to the stewardship of this critical coastal system.

This is scenario 4 for Popponesset Bay or Scenario 07-1.

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[1] Howes, B.L, R.I. Samimy, D.R. Schlezinger, J. Ramsey, S. Kelley, E. Eichner. 2004. et al. Massachusetts Estuaries Project: Linked Watershed-Embayment Management Modeling to Determine Critical Nitrogen Loading Thresholds for Popponesset Bay, Mashpee and Barnstable, MA. Final Report to MA Department of Environmental Protection and USEPA, 137pp. Published by MADEP.

The MEP Technical Team working from data provided by the Town of Mashpee ran the calibrated/validated Linked Watershed-Embayment Model for the following scenario. The scenario was developed to provide information for the development of an approach to load allocation decisions when an estuary's watershed contains inputs from multiple towns.

Scenario 07-1: The Nitrogen Load from all sources within the watershed to the Popponesset Bay Estuarine System were reduced by 49.2% (at the source). The watershed sources reduced were:

- **Septic Systems**
- **Wastewater Treatment Facilities**
- **Fertilizers (lawn, agriculture, golf courses)**
- **Impervious Surface Discharges**
- **Freshwater Bodies (Atmospheric inputs to lakes, ponds, rivers, etc)**
- **Natural Surfaces (forests, fields)**

Direct atmospheric deposition to the estuary surface was left unchanged. While some of the watershed sources clearly will not be part of a nitrogen management program, they were reduced in N load for this conceptual scenario for the Town of Mashpee.

The goal was to determine if a constant watershed nitrogen loading reduction (evenly applied to all watershed sources) could be developed and meet the nitrogen threshold set for Popponesset Bay (Table 1). Based upon data developed by the Pilots Project, a constant reduction of 49.2% was used for the modeling and the watershed loading (Table 2) developed from the Watershed Loading Model.

Model Output: If all of the nitrogen sources within the Popponesset Bay System watershed are reduced (at the source) by 49,2%, the nitrogen threshold for the receiving estuarine waters is attained. The sentinel station is lowered to 0.352 mg TN/L, below the Threshold Scenario developed in the MEP Technical Report of 0.372 mg TN/L and well below the TMDL N Threshold of 0.380 mg TN/L. All of the infauna "check" stations also were well within the acceptable range (0.4-0.5 mg TN/L). The nitrogen reductions produced by this scenario would be sufficient to restore the eelgrass and infaunal animal habitats throughout this estuarine system.

Table 1. Comparison of TN concentrations for present conditions, threshold loading, and four modeled loading scenarios for the Popponesset Bay system. Threshold concentrations are 0.380 mg/L TN for eelgrass (primary), and between 0.400 and 0.500 mg/L TN for infauna (secondary). .

Sentinel & "Check" Sub-embayments	Restoration Goal	Present (mg TN/L)	Threshold (mg TN/L)	Scenario 4 (mg TN/L)
Popponesset Bay - head	Eelgrass	0.464	0.372	0.359
Mashpee River - mid to lower	Infauna	0.712	0.472	0.458
Shoestring Bay - upper to lower	Infauna	0.631	0.469	0.423
Ockway Bay - upper	Infauna	0.567	0.423	0.426

Table 2. Comparison of sub-embayment watershed loads used for modeling of present, threshold and scenario loading conditions of the Popponesset Bay system. These loads do not include direct atmospheric deposition (onto the sub-embayment surface) or benthic flux loading terms.

sub-embayment	present load (kg/day)	threshold (kg/day)	at threshold % change	Scenario 4 (kg/day)	Scenario 4 % change
Popponesset Bay	1.819	1.819	0.0%	0.925	-49.2 %
Popponesset Creek	4.940	0.953	-80.7%	2.510	-49.2%
Pinquickset Cove	0.764	0.764	0.0%	0.388	-49.2%
Ockway Bay	3.151	0.757	-76.0%	1.600	-49.2%
Mashpee River	12.107	2.500	-79.4%	6.151	-49.2%
Shoestring Bay	9.208	2.260	-75.5%	4.677	-49.2%
Surface Water Sources					
Mashpee River	21.888	13.668	-37.6%	11.118	-49.2%
Santuit River	15.584	11.474	-26.4%	7.923	-49.2%
Quaker Run River	5.984	5.983	0.0%	3.038	-49.2%
TOTAL	75.445	40.178	-46.7%	38.330	-49.2%

APPENDIX M

SMAST The School for Marine Science and Technology University of Massachusetts Dartmouth

Massachusetts Department of Environmental Protection

Massachusetts Estuaries Project

Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Three Bays System Barnstable, Massachusetts

Executive Summary

1. Background

This report presents the results generated from the implementation of the Massachusetts Estuaries Project's Linked Watershed-Embayment Approach to the Three Bays embayment system, a coastal embayment within the Town of Barnstable, Massachusetts. Analyses of the Three Bays embayment system was performed to assist the Town with up-coming nitrogen management decisions associated with the Towns' current and future wastewater planning efforts, as well as wetland restoration, anadromous fish runs, shell fishery, open-space, and harbor maintenance programs. As part of the MEP approach, habitat assessment was conducted on the embayment based upon available water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure. Nitrogen loading thresholds for use as goals for watershed nitrogen management are the major product of the MEP effort. In this way, the MEP offers a science-based management approach to support the Town of Barnstable resource planning and decision-making process. The primary products of this effort are: (1) a current quantitative assessment of the nutrient related health of the Three Bays embayment, (2) identification of all nitrogen sources (and their respective N loads) to embayment waters, (3) nitrogen threshold levels for maintaining Massachusetts Water Quality Standards within embayment waters, (4) analysis of watershed nitrogen loading reduction to achieve the N threshold concentrations in embayment waters, and (5) a functional calibrated and validated Linked Watershed-Embayment modeling tool that can be readily used for evaluation of nitrogen management alternatives (to be developed by the Town) for the restoration of the Three Bays embayment system.

Wastewater Planning: As increasing numbers of people occupy coastal watersheds, the associated coastal waters receive increasing pollutant loads. Coastal embayments throughout the Commonwealth of Massachusetts (and along the U.S. eastern seaboard) are becoming nutrient enriched. The elevated nutrient levels are primarily related to the land use impacts associated with the increasing population within the coastal zone over the past half-century.

The regional effects of both nutrient loading and bacterial contamination span the spectrum from environmental to socio-economic impacts and have direct consequences to the culture, economy, and tax base of Massachusetts's coastal communities. The primary nutrient causing the increasing impairment of our coastal embayments is nitrogen, with its primary sources being wastewater disposal, and nonpoint source runoff that carries nitrogen (e.g. fertilizers) from a range of other sources. Nitrogen related water quality decline represents one of the most serious threats to the ecological health of the nearshore coastal waters. Coastal embayments, because of their shallow nature and large shoreline area, are generally the first coastal systems to show the effect of nutrient pollution from terrestrial sources.

In particular, the Three Bays embayment system within the Town of Barnstable is at risk of eutrophication (over enrichment) from enhanced nitrogen loads entering through groundwater from the increasingly developed watershed to this coastal system. Eutrophication is a process that occurs naturally and gradually over a period of tens or hundreds of years. However, human-related (anthropogenic) sources of nitrogen may be introduced into ecosystems at an accelerated rate that cannot be easily absorbed, resulting in a phenomenon known as cultural eutrophication. In both marine and freshwater systems, cultural eutrophication results in degraded water quality, adverse impacts to ecosystems, and limits on the use of water resources.

The Town of Barnstable has recognized the severity of the problem of eutrophication and the need for watershed nutrient management and is currently developing a Comprehensive Wastewater Management Plan, which it plans to rapidly implement. The Town of Barnstable has also completed and implemented wastewater planning in other regions of the Town not associated with the Three Bays embayment system. The Town has nutrient management activities related to their tidal embayments, which have been associated with the MEP effort in the Centerville River/Harbor and the Lewis Bay embayment systems. The Town of Barnstable and work groups have recognized that a rigorous scientific approach yielding site-specific nitrogen loading targets was required for decision-making and alternatives analysis. The completion of this multi-step process has taken place under the programmatic umbrella of the Massachusetts Estuaries Project, which is a partnership effort between all MEP collaborators and the Town. The modeling tools developed as part of this program provide the quantitative information necessary for the Towns' nutrient management groups to predict the impacts on water quality from a variety of proposed management scenarios.

Nitrogen Loading Thresholds and Watershed Nitrogen Management: Realizing the need for scientifically defensible management tools has resulted in a focus on determining the aquatic system's assimilative capacity for nitrogen. The highest-level approach is to directly link the watershed nitrogen inputs with embayment hydrodynamics to produce water quality results that can be validated by water quality monitoring programs. This approach when linked to state-of-the-art habitat assessments yields accurate determination of the "allowable N concentration increase" or "threshold nitrogen concentration". These determined nitrogen concentrations are then directly relatable to the watershed nitrogen loading, which also accounts for the spatial distribution of the nitrogen sources, not just the total load. As such, changes in nitrogen load from differing parts of the embayment watershed can be evaluated relative to the degree to which those load changes drive embayment water column nitrogen concentrations toward the "threshold" for the embayment system. To increase certainty, the "Linked" Model is independently calibrated and validated for each embayment.

Massachusetts Estuaries Project Approach: The Massachusetts Department of Environmental Protection (DEP), the University of Massachusetts – Dartmouth School of Marine Science and Technology (SMAST), and others including the Cape Cod Commission (CCC) have undertaken the task of providing a quantitative tool to communities throughout southeastern Massachusetts (the Linked Watershed-Embayment Management Model) for nutrient management in their coastal embayment systems. Ultimately, use of the Linked Watershed-Embayment Management Model tool by municipalities in the region results in effective screening of nitrogen reduction approaches and eventual restoration and protection of valuable coastal resources. The MEP provides technical guidance in support of policies on nitrogen loading to embayments, wastewater management decisions, and establishment of nitrogen Total Maximum Daily Loads (TMDLs). A TMDL represents the greatest amount of a pollutant that a waterbody can accept and still meet water quality standards for protecting public health and maintaining the designated beneficial uses of those waters for drinking, swimming, recreation and fishing. The MEP modeling approach assesses available options for meeting selected nitrogen goals that are protective of embayment health and achieve water quality standards.

The core of the Massachusetts Estuaries Project analytical method is the Linked Watershed-Embayment Management Modeling Approach, which links watershed inputs with embayment circulation and nitrogen characteristics.

The Linked Model builds on well-accepted basic watershed nitrogen loading approaches such as those used in the Buzzards Bay Project, the CCC models, and other relevant models. However, the Linked Model differs from other nitrogen management models in that it:

- requires site-specific measurements within each watershed and embayment;
- uses realistic "best-estimates" of nitrogen loads from each land-use (as opposed to loads with built-in "safety factors" like Title 5 design loads);
- spatially distributes the watershed nitrogen loading to the embayment;
- accounts for nitrogen attenuation during transport to the embayment;
- includes a 2D or 3D embayment circulation model depending on embayment structure;
- accounts for basin structure, tidal variations, and dispersion within the embayment;
- includes nitrogen regenerated within the embayment;
- is validated by both independent hydrodynamic, nitrogen concentration, and ecological data;
- is calibrated and validated with field data prior to generation of "what if" scenarios.

The Linked Model Approach's greatest assets are its ability to be clearly calibrated and validated, and its utility as a management tool for testing "what if" scenarios for evaluating watershed nitrogen management options.

For a comprehensive description of the Linked Model, please refer to the *Full Report: Nitrogen Modeling to Support Watershed Management: Comparison of Approaches and Sensitivity Analysis*, available for download at http://www.state.ma.us/dep/smerp/smerp.htm. A more basic discussion of the Linked Model is also provided in Appendix F of the *Massachusetts Estuaries Project Embayment Restoration Guidance for Implementation Strategies*, available for download at http://www.state.ma.us/dep/smerp/smerp.htm. The Linked Model suggests which management solutions will adequately protect or restore embayment water quality by enabling towns to test specific management scenarios and weigh the resulting water quality impact against the cost of that approach. In addition to the management scenarios modeled for this report, the Linked Model can be used to evaluate additional management scenarios and may be updated to reflect future changes in land-use within an embayment watershed or changing embayment characteristics. In addition, since the Model uses a holistic approach (the entire watershed, embayment and tidal source waters), it can be used to evaluate all projects as they relate directly or indirectly to water quality conditions within its geographic boundaries. Unlike many approaches, the Linked Model accounts for nutrient sources, attenuation, and recycling and variations in tidal hydrodynamics and accommodates the spatial distribution of these processes. For an overview of several management scenarios that may be employed to restore embayment water quality, see *Massachusetts Estuaries Project Embayment Restoration Guidance for Implementation Strategies*, available for download at http://www.state.ma.us/dep/smerp/smerp.htm.

Application of MEP Approach: The Linked Model was applied to the Three Bays embayment system by using site-specific data collected by the MEP and water quality data from the Water Quality Monitoring Program conducted by Three Bays Preservation in partnership with the Town of Barnstable, with technical guidance from the Coastal Systems Program at SMAST (see Chapter 2). Evaluation of upland nitrogen loading was conducted by the MEP, data was provided by the Town of Barnstable Planning Department, and watershed boundaries delineated by USGS. This land-use data was used to determine watershed nitrogen loads within the Three Bays embayment system and each of the systems sub-embayments as appropriate (current and build-out loads are summarized in Table IV-5). Water quality within a sub-embayment is the integration of nitrogen loads with the site-specific estuarine circulation. Therefore, water quality modeling of this tidally influenced estuary included a thorough evaluation of the hydrodynamics of the estuarine system. Estuarine hydrodynamics control a variety of coastal processes including tidal flushing, pollutant dispersion, tidal currents, sedimentation, erosion, and water levels. Once the hydrodynamics of the system was quantified, transport of nitrogen was evaluated from tidal current information developed by the numerical models.

A two-dimensional depth-averaged hydrodynamic model based upon the tidal currents and water elevations was employed for the Three Bays embayment system. Once the hydrodynamic properties of the estuarine system were computed, two-dimensional water quality model simulations were used to predict the dispersion of the nitrogen at current loading rates. Using standard dispersion relationships for estuarine systems of this type, the water quality model and the hydrodynamic model was then integrated in order to generate estimates regarding the spread of total nitrogen from the site-specific hydrodynamic properties. The distributions of nitrogen loads from watershed sources were determined from land-use analysis. Boundary nutrient concentrations in Vineyard Sound source waters were taken from water quality monitoring data. Measurements of current salinity distributions throughout the estuarine waters of the Three Bays embayment system was used to calibrate the water quality model, with validation using measured nitrogen concentrations (under existing loading conditions). The underlying hydrodynamic model was calibrated and validated independently using water elevations measured in time series throughout the embayments.

MEP Nitrogen Thresholds Analysis: The threshold nitrogen level for an embayment represents the average water column concentration of nitrogen that will support the habitat quality being sought. The water column nitrogen level is ultimately controlled by the watershed nitrogen load and the nitrogen concentration in the inflowing tidal waters (boundary condition). The water column nitrogen concentration is modified by the extent of sediment regeneration. Threshold nitrogen levels for the embayment systems in this study were developed to restore or maintain SA waters or high habitat quality. High habitat quality was defined as supportive of

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eelgrass and infaunal communities. Dissolved oxygen and chlorophyll a were also considered in the assessment.

The nitrogen thresholds developed in Section VIII-2 were used to determine the amount of total nitrogen mass loading reduction required for restoration of eelgrass and infaunal habitats in the Rushy Marsh system. Tidally averaged total nitrogen thresholds derived in Section VIII.1 were used to adjust the calibrated constituent transport model developed in Section VI. Watershed nitrogen loads were sequentially lowered, using reductions in septic effluent discharges only, until the nitrogen levels reached the threshold level at the sentinel station chosen for the Three Bays system. It is important to note that load reductions can be produced by reduction of any or all sources or by increasing the natural attenuation of nitrogen within the freshwater systems to the embayment. The load reductions presented below represent only one of a suite of potential reduction approaches that need to be evaluated by the community. The presentation is to establish the general degree and spatial pattern of reduction that will be required for restoration of this nitrogen impaired embayment.

The Massachusetts Estuaries Project's thresholds analysis, as presented in this technical report, provides the site-specific nitrogen reduction guidelines for nitrogen management of the Three Bays embayment system in the Town of Barnstable. Future water quality modeling scenarios should be run which incorporate the spectrum of strategies that result in nitrogen loading reduction to the embayment. The MEP analysis has initially focused upon nitrogen loads from on-site septic systems as a test of the potential for achieving the level of total nitrogen reduction for restoration of each embayment system. The concept was that since septic system nitrogen loads generally represent 85% - 90% of the controllable watershed load to the Three Bays embayment system and are more manageable than other of the nitrogen sources, the ability to achieve needed reductions through this source is a good gauge of the feasibility for restoration of these systems.

2. Problem Assessment (Current Conditions)

A habitat assessment was conducted throughout The Three Bays system based upon available water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure. At present, the Three Bays system is showing significantly impaired to severely degraded habitat quality in the Prince's Cove and Warren's Cove sub-embayments as well as the upper portion of North Bay. The lower portion of North Bay as well as Eel River are showing indications of moderate bordering on significant impairment while Cotuit Bay and West Bay are both showing signs of moderate impairment. All of the habitat indicators are consistent with this evaluation of the whole of system (Chapter VII).

The effect of nitrogen enrichment is to cause oxygen depletion; however, with increased phytoplankton (or epibenthic algae) production, oxygen levels will rise in daylight to above atmospheric equilibration levels in shallow systems (generally ~7-8 mg L^{-1} at the mooring sites). The clear evidence of oxygen levels above atmospheric equilibration indicates that the Three Bays system is eutrophic.

The level of oxygen depletion and the magnitude of daily oxygen excursion and chlorophyll a levels indicate highly nutrient enriched waters and impaired habitat quality within the estuary. The major sub-embayments to the Three Bays system (Cotuit Bay, West Bay, North Bay and Prince's Cove) are currently under seasonal oxygen stress, consistent with nitrogen enrichment (Chapter VII). That the cause is nitrogen enrichment is supported by parallel observations of chlorophyll a (Table VII-2). Oxygen conditions and chlorophyll a levels generally improved with decreasing distance to the tidal inlet, although all basins showed oxygen depletions to <4 mg L^{-1}. There was also a clear gradient in chlorophyll a, with highest levels in the uppermost reaches and lowest levels near the tidal inlet to Nantucket Sound. The results of the summer oxygen and chlorophyll a studies are consistent with the absence of eelgrass throughout the Three Bays System and the near absence of animal communities throughout the upper basins where oxygen depletions routinely dropped below 3 mg/L.

Currently, there are no remaining eelgrass beds within the Three Bays System. However, it appears that all of the major sub-embayments had water quality conditions capable of supporting eelgrass (except in the deeper channels and basin depths) in 1951. However, eelgrass appears to have been restricted to the shallows (North and Cotuit Bays) or to Prince's Cove and West Bay basins. If the issue in 1951 was nitrogen enrichment, the pattern of the beds would have been very different, with more eelgrass in lower Cotuit Bay and West Bay and much less in Prince's Cove and North Bay (except in the very shallows). Instead, it is likely that disturbance related to activities in North and Cotuit Bays associated with training during WWII played a role in the North and Cotuit Bay pattern of beds in the 1951 assessment. Whatever the cause, it is clear that in the recent past, the Three Bays system was capable of supporting eelgrass within each of its major sub-embayments. It also appears that the recent losses (post 1951) are associated with nitrogen enrichment, as in virtually every other embayment in southeastern Massachusetts. The absence of eelgrass in each basin and the fact that they supported eelgrass in the recent past classifies each basins eelgrass habitat as "significantly impaired" (Table VIII-1).

The current absence of eelgrass in each of the major sub-embayments of the Three Bays System is consistent with the observed oxygen depletions in each basin and the high chlorophyll levels in the upper regions. The greater depths in the Three Bays Estuary also makes oxygen depletions more likely than in shallow basins with the same nitrogen levels. This results from the fact that deeper systems are more likely to periodically stratify. The central deep basins in North Bay and Prince's Cove are particularly sensitive to eelgrass loss as it takes less intense phytoplankton blooms to reduce light penetration to the bottom, and thereby prevent eelgrass growth. In addition, the basins are sensitive to periodic oxygen depletion. At this time, it is not clear if these regions have historically (100 years) supported eelgrass. However, eelgrass beds fringing these basins are well documented. As regards the lack of eelgrass within the lowermost portion of Cotuit Bay and the Seapuit River, it is likely associated with the documented highly dynamic coastal processes in this area. The level of natural disturbance in this region is very high (sand transport, overwash, etc). Physical stability is important to the ability of eelgrass beds to form and persist.

The Infauna Study indicated that most of the upper areas of the Three Bays system are presently significantly impaired to severely degraded by nitrogen enrichment (Prince's Cove, Warren's Cove and portions of North Bay), while the lower basins of Cotuit Bay and West Bay are moderately impaired (Table VII-4). Prince's Cove, Warren's Cove and 2 of 3 sites in North Bay are virtually devoid of infaunal animal communities. The central region of North Bay currently supports a transitional community dominated by amphipods, indicative of organic matter enrichment. In contrast, Cotuit and West Bays generally have ~500-2000 individuals per grab and 16-26 species. While there are stress indicator species (generally *Capitella* or *Streblospio*) in numbers at these locations there are also other species indicative of a healthy environment and overall high diversity. Overall, the pattern of infaunal community quality is consistent with the pattern of oxygen depletion and chlorophyll a during summer and the absence of eelgrass. All sites showed some level of degradation, either in number of individuals, diversity or the presence of stress indicator species.

3. Conclusions of the Analysis

The threshold nitrogen level for an embayment represents the average watercolumn concentration of nitrogen that will support the habitat quality being sought. The watercolumn nitrogen level is ultimately controlled by the integration of the watershed nitrogen load, the nitrogen concentration in the inflowing tidal waters (boundary condition) and dilution and flushing via tidal flows. The water column nitrogen concentration is modified by the extent of sediment regeneration and by direct atmospheric deposition.

Threshold nitrogen levels for this embayment system were developed to restore or maintain SA waters or high habitat quality. In this system, high habitat quality was defined as possibly supportive of eelgrass and supportive of diverse benthic animal communities. Dissolved oxygen and chlorophyll *a* were also considered in the assessment.

Watershed nitrogen loads (Tables ES-1 and ES-2) for the Town of Barnstable Three Bays embayment system was comprised primarily of wastewater nitrogen. Land-use and wastewater analysis found that generally about 80% - 85% of the controllable watershed nitrogen load to the embayment was from wastewater.

A major finding of the MEP clearly indicates that a single total nitrogen threshold can not be applied to Massachusetts' estuaries, based upon the results of the Great, Green and Bournes Pond Systems, Popponesset Bay System, the Hamblin / Jehu Pond / Quashnet River analysis in eastern Waquoit Bay, the analysis of the adjacent Rushy Marsh system and the Pleasant Bay and Nantucket Sound embayments associated with the Town of Chatham. This is almost certainly going to be true for the other embayments within the MEP area, as well.

The threshold nitrogen levels for the Three Bays embayment system in Barnstable were determined as follows:

Three Bays Threshold Nitrogen Concentrations

- Following the MEP protocol, the restoration target for the Three Bays system should reflect both recent pre-degradation habitat quality and be reasonably achievable. Based upon the assessment data (Chapter VII), eelgrass bed restoration within Cotuit Bay and West Bay, with restoration of marginal beds in North Bay and Prince's Cove is supportable. In addition, in the central basins of North Bay and Prince's Cove, where eelgrass habitat has not been documented, as well as in Warren's Cove, restoration of infaunal habitat is necessary. Achieving these habitat quality targets will also result in mitigation of the present macroalgal accumulation problem in Warren's Cove. To achieve these habitat restoration targets, for the Three Bays system a single sentinel location was selected with secondary criteria that must be achieved at other locations. The secondary criteria serve only as checks to make sure that the targets are achieved when the nitrogen threshold at the sentinel station has been reached.
- The target nitrogen concentration for restoration of eelgrass in this system was determined to be 0.38 mg TN L^{-1} at the sentinel location and 0.40 mg TN L^{-1} within the marginal regions (shallows) of North Bay. This secondary level to check restoration of marginal beds in North Bay (O.40 mg TN L^{-1}) is consistent with the analysis of

restoration of fringing eelgrass beds in nearby Great Pond, and analysis where eelgrass beds in deep waters could not be supported at a tidally averaged TN of 0.412 mg TN L^{-1} at depths of 2 m. Similarly prior MEP analysis in Bournes Pond indicated that tidally averaged TN levels of 0.42 mg TN L^{-1} excluded beds from all but the shallowest water. The MEP Technical Team cannot specify the exact extent of marginal beds to be restored in the upper deep basins. At tidally averaged TN levels of 0.42 mg TN L^{-1} the eelgrass habitat would be restricted to very shallow waters, while at 0.40 mg TN L^{-1} the eelgrass habitat should reach to 1-2 meters depth, based upon the data from nearby systems. In addition, the persistence of eelgrass beds through 1995-2001 in the shallow waters of south Windmill Cove, but in a stable physical setting, were at nitrogen levels (tidally averaged TN ~0.40 mg L-1).

- Since infaunal animal habitat is also a critical resource to the Three Bays System, the secondary metric for a successful restoration (after eelgrass) will be to restore the significantly impaired/severely degraded habitats in the Prince's Cove/Warren's Cove and North Bay basins. In the upper more muddy basins of other nearby systems, healthy infaunal habitat is associated with nitrogen levels of TN <0.5 mg TN L^{-1}. This was found for Popponesset Bay where based upon the infaunal analysis coupled with the nitrogen data (measured and modeled), nitrogen levels on the order of 0.4 to 0.5 mg TN L-1 were found supportive of high infaunal habitat quality in this system. In the Three Bays System, present healthy infaunal areas are found at nitrogen levels of TN <0.42 mg TN L^{-1} (Cotuit Bay and West Bay) However, the impaired areas are at nitrogen levels of TN >0.5 mg TN L^{-1} (North Bay) and are severely degraded at nitrogen levels of TN >0.6 mg TN L^{-1}. This is consistent with the findings discussed above from other systems and fully supports a secondary nitrogen criteria for the upper muddy basins of 0.5 mg TN L^{-1}.

It is important to note that the analysis of future nitrogen loading to the Three Bays estuarine system focuses upon additional shifts in land-use from forest/grasslands to residential and commercial development. However, the MEP analysis indicates that significant increases in nitrogen loading can occur under present land-uses, due to shifts in occupancy, shifts from seasonal to year-round useage and increasing use of fertilizers (presently less than half of the parcels use lawn fertilizers). Therefore, watershed-estuarine nitrogen management must include management approaches to prevent increased nitrogen loading from both shifts in land-uses (new sources) and from loading increases of current land-uses. The overarching conclusion of the MEP analysis of the Three Bays estuarine system is that restoration will necessitate a reduction in the present (2004) nitrogen inputs and management options to negate additional future nitrogen inputs.

Table ES-1. Existing total and sub-embayment nitrogen loads to the estuarine waters of the Three Bays system, observed nitrogen concentrations, and sentinel system threshold nitrogen concentrations. Loads to estuarine waters of the Three Bays system include both upper watershed regions contributing to the major surface water inputs (Marstons Mills River and Little River).

Sub-embayments	Natural Background Watershed Load [1] (kg/day)	Present Land Use Load [2] (kg/day)	Present Septic System Load (kg/day)	Present WWTF Load [3] (kg/day)	Present Watershed Load [4] (kg/day)	Direct Atmospheric Deposition [5] (kg/day)	Present Net Benthic Flux (kg/day)	Present Total Load [6] (kg/day)	Observed TN Conc. [7] (mg/L)	Threshold TN Conc. (mg/L)
THREE BAYS SYSTEM										
Cotuit Bay [a]	2.447	5.515	20.225	--	25.740	5.786	-54.443	-22.917	0.39-0.44	--
West Bay	1.170	3.578	15.490	--	19.068	4.233	3.815	27.117	0.38-0.48	--
Seapuit River	0.452	0.847	2.921	0.016	3.767	0.452	-5.418	-1.199	0.32	--
North Bay	1.970	4.468	24.978	--	29.447	3.953	67.522	100.922	0.50-0.52	--
Prince's Cove [a]	3.964	10.337	24.836	0.092	35.173	1.230	0.512	36.914	0.60-0.70	--
Warren Cove	1.945	5.052	6.975	--	12.027	--	8.830	20.857	0.64	--
Prince's Cove Channel	0.515	0.770	4.767	--	5.537	--	2.345	7.882	0.64	--
Three Bays System Total	12.463	30.567	100.192	0.108	130.759	15.655	23.162	169.576	**0.32-0.70**	0.38

[1] assumes entire watershed is forested (i.e., no anthropogenic sources)
[2] composed of non-wastewater loads, e.g. fertilizer and runoff and natural surfaces and atmospheric deposition to lakes
[3] existing wastewater treatment facility discharges to groundwater
[4] composed of combined natural background, fertilizer, runoff, and septic system loadings
[5] atmospheric deposition to embayment surface only. Warren Cove and Prince's Cove Channel atmospheric loads are included with the Prince's Cove Load.
[6] composed of natural background, fertilizer, runoff, septic system atmospheric deposition and benthic flux loadings
[7] average of 1999 – 2004 data, ranges show the upper to lower regions (highest-lowest) of a sub-embayment.
[8] Eel grass threshold for sentinel site located at "The Narrows" between North Bay and Cotuit Bay (0.38 mg/L TN), and infaunal target for Prince's Cove of 0.50 mg/L TN.
[a] Include loads from surface water sources (i.e., Marstons Mills River to Prince's Cove and Little River to Cotuit Bay).

Table ES-2. Present Watershed Loads, Threshold Loads and the percent reductions necessary to achieve the Threshold Loads for the Three Bays system.

Sub-embayments	Present Watershed Load [1] (kg/day)	Target Threshold Watershed Load [2] (kg/day)	Direct Atmospheric Deposition (kg/day)	Benthic Flux Net [3] (kg/day)	Percent watershed reductions needed to achieve threshold load levels
THREE BAYS SYSTEM					
Cotuit Bay	25.740	22.335	5.786	-45.788	-13.2%
West Bay	19.068	15.970	4.233	3.469	-16.2%
Seapuit River	3.767	3.767	0.452	-5.371	0.0%
North Bay	29.447	4.468	3.953	45.202	-84.8%
Prince's Cove	35.173	17.890	1.230	0.323	-49.1%
Warren Cove	12.027	5.052	--	6.225	-58.0%
Prince's Cove Channel	5.537	0.770	--	1.541	-86.1%
Three Bays System Total	130.759	70.254	15.655	5.602	-46.3%

(1) Composed of combined natural background, fertilizer, runoff, and septic system loadings.
(2) Target Threshold Watershed Load is the load from the watershed needed to meet the embayment threshold concentration identified in Table ES-1.
(3) Projected future flux (present rates reduced approximately proportional to watershed load reductions).

Executive Summary 10

APPENDIX N

SMAST
University of Massachusetts Dartmouth
The School for Marine Science and Technology

************************ **Technical Memorandum** ****************************

To: George Zoto, MassDEP Pilots Project Coordinator
Dale Saad, Barnstable Special Project Manager
Mark Ells, Barnstable Department of Public Works
David Mason, Sandwich Health Department
Tom Fudala, Mashpee Planning Department
Lindsey Counsell, Three Bays Preservation
From: Brian Howes, Director Coastal Systems Program
Roland Samimy, Coastal Systems Program
John Ramsey, Applied Coastal Research & Engineering, Inc.
Sean Kelley, Applied Coastal Research & Engineering, Inc.
Ed Eichner, Cape Cod Commission
RE: Scenario Runs of Popponesset Bay MEP Linked Model
Date: December 26, 2007
****

The present Technical Memorandum details the results of 3 Scenario Runs of the MEP Linked Watershed-Embayment Model developed for the Three Bays System as described in the MassDEP/SMAST MEP Nitrogen Threshold Report for the Three Bays Estuary[1]. The Scenarios focus on 2 issues: Scenarios 1 & 2 remove nitrogen presently discharged to the watershed through on-site Title 5 septic systems and process at a wastewater treatment facility and discharge within the Three Bays watershed; Scenario 3 was a request for the amount of nitrogen originating within each of the three towns which comprise the watershed to Three Bays.

At present, historic eelgrass and benthic animal habitat within Three Bays Estuary is significantly impaired owing to watershed nitrogen inputs that exceed this estuary's assimilative capacity, resulting in eutrophic conditions. As part of nitrogen management planning the Towns of Barnstable, Mashpee and Sandwich, with the MassDEP Pilots Project have worked with SMAST in the use of the MEP Linked Model developed for this estuary. The present effort is the first round of scenario runs for the Three Bays System.

The present scenarios were provided by the Barnstable DPW (Dale Saad), in order to provide additional information to MassDEP, municipal officials, private citizens and environmental groups to support decisions regarding the nitrogen management planning and load allocation decisions related to the stewardship of this critical coastal system.

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[1] Howes, B.L., S.W. Kelley, J.S. Ramsey, R.I. Samimy, D.R. Schlezinger, E. Eichner. 2006. Linked Watershed-Embayment Modeling Approach to Determine Critical Nitrogen Loading Thresholds for Three Bays, Barnstable, MA. Massachusetts Estuaries Project Final Report to Massachusetts Department of Environmental Protection, Boston MA. 183pp.

Scenario 1: The Nitrogen Load from Title 5 septic systems within selected sub-watersheds to the Three Bays Estuary was to be collected by sewers, treated at a Town WWTF with treated effluent at 5 mg TN L^{-1} undergoing groundwater disposal of at 2 sites within the Three Bays watershed.

The sub-watersheds to Three Bays from the MEP Technical Report[1] are shown in Figure 1, below, and the sub-watersheds with the % of septic systems to be connected to the WWTF(s) are presented in the following table (Table 1). The locations of the groundwater disposal sites are shown as "Site A" and "Site B" in Figure 2. Given the placement of the parcels within their sub-watersheds the effluent was assumed to not alter the sub-watershed boundaries. If the need arises, assessment of effects of effluent disposal on watershed boundaries can be determined by groundwater modeling knowing the volumetric discharge at each disposal site.

Based upon the information in Table 1, the N loading changes from this scenario were developed and are presented in Tables 2 & 3. These new N loads were then processed through the calibrated and validated Linked Watershed-Embayment Model for the Three Bays System to determine changes in the nitrogen levels within the estuarine waters.

Model Output: Three Bays Sentinel Station falls between upper Cotuit Bay (TB-12) and North Bay South (TB-6) in its N level. The target (threshold) TN level at the Sentinel Station is 0.380 mg/L for restoration of this estuary. While Scenario 1 did remove significant amounts of wastewater nitrogen from the upper region of the Three Bays watershed, the TN level within the estuary remained well above the restoration target at the Sentinel Station, 0.454 mg/L versus 0.380 mg/L. Both North Bay stations, which should be below 0.400 mg TN L-1, reach only 0.484 and 0.469 mg/L, showing less than a 7% decline (Table 4). As expected from the location of the N removed, the largest change in estuarine water quality was seen in Prince Cove, Warrens Cove and North Bay. In addition, the infauna "check" stations were well above the acceptable range (0.4-0.5 mg TN/L), indicating infaunal animal habitat remains degraded in these basins.

Part of the reason for these results stems from the removal of septic N load in sub-watersheds to ponds, bogs and wetlands, which support nitrogen removal during transport of N through them to the estuary. Removal of N load in these areas has a lower proportional removal of N loading to the estuary, than managing sources which discharge groundwater directly to the estuary.

The nitrogen reductions produced by this scenario are insufficient to restore the eelgrass and infaunal animal habitats throughout this estuarine system.

Table 1. Two Treatment Facilities (5 mg/l N) And Discharge Areas.

Discharge Area "A" located in Prince Cove GT10

Sub-embayment	Percent Treated and Discharged to Area "A"
Prince Cove LT10	100
North Bay GT10W	100
North Bay LT10	20
Upper Marstons Mills River	10
Prince Cove GT10	5
Lower Marstons Mills River LT10	20

Discharge Area "B" located in Middle Marstons Mills LT10

Sub-embayment	Percent Treated and Discharged to Area "B"
Upper Marstons Mills River	90
Lower Marstons Mills River LT10	55
Lower Marstons Mills River GT10	40
Middle Marstons Mills River LT10	80
Bog Pond LT10	60
Bog Pond GT10	90
COMM Davis/Arena/McShane Wells	90
North Bay GT10E	30
Joshua Pond GT10	90
Joshua Pond LT10	60
Micah Pond	95

Table 2. Comparison of sub-embayment ***total watershed loads*** (including septic, runoff, and fertilizer) used for modeling of present conditions and the two loading Scenarios for the Three Bays system. These loads do not include direct atmospheric deposition (onto the sub-embayment surface) or benthic flux loading terms.

sub-embayment	present load (kg/day)	Scenario 1 load (kg/day)	Scenario 1 % change	Scenario 2 load (kg/day)	Scenario 2 % change
Cotuit Bay	21.778	21.778	+0.0%	21.778	+0.0%
West Bay	18.866	18.866	+0.0%	18.866	+0.0%
Seaptuit River	3.767	3.767	+0.0%	3.767	+0.0%
North Bay	29.447	19.118	-35.1%	19.118	-35.1%
Prince Cove	13.362	8.600	-35.6%	5.468	-59.1%
Warrens Cove	12.027	12.027	+0.0%	12.027	+0.0%
Prince Cove Channel	5.537	5.537	+0.0%	5.537	+0.0%
Marstons Mills Crescent	7.293	7.293	+0.0%	7.293	+0.0%
Surface Water Sources					
Marstons Mills River	14.518	9.868	-32.0%	10.203	-29.7%
Little River	3.962	3.962	+0.0%	3.962	+0.0%

Scenario Runs 1-3 for the Three Bays Estuary *MEP Technical Team 12-26-07*

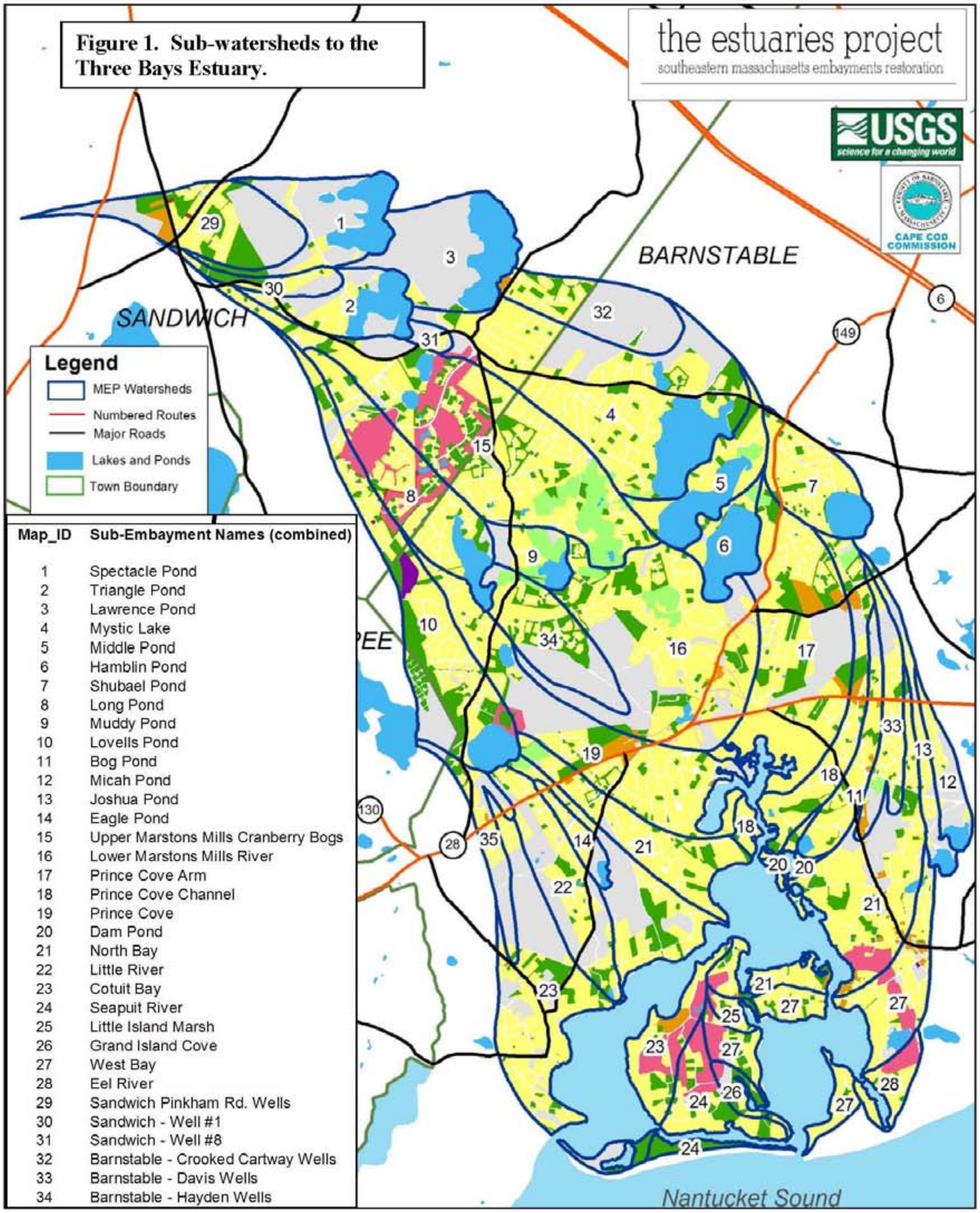
Table 3. **Scenario 1** sub-embayment and surface water loads used for total nitrogen modeling of the Three Bays system, with total watershed N loads, atmospheric N loads, and benthic flux

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)
Cotuit Bay	21.778	5.786	-51.314
West Bay	18.866	4.233	3.764
Seaptuit River	3.767	0.452	-5.246
North Bay	19.118	3.953	62.329
Prince Cove	8.600	1.230	0.464
Warrens Cove	12.027	-	8.080
Prince Cove Channel	5.537	-	2.136
Marstons Mills Crescent	7.293	-	-
Surface Water Sources			
Marstons Mills River	9.868	-	-
Little River	3.962	-	-

Table 4. Comparison of model average total N concentrations from present loading and the two loading scenarios, with percent change, for the Three Bays system. Loads are based on atmospheric deposition and a scaled N benthic flux (scaled from present conditions).

Sub-Embayment	monitoring station	present (mg/L)	**Scenario 1 (mg/L)**	**Scenario 1 % change**	Scenario 2 (mg/L)	Scenario 2 % change
Prince Cove - south	TB2	0.695	**0.616**	**-11.3%**	0.584	-15.9%
Prince Cove - north	TB3	0.639	**0.578**	**-9.5%**	0.557	-12.7%
Warrens Cove	TB4	0.595	**0.548**	**-7.9%**	0.535	-10.0%
North Bay - north	TB5	0.518	**0.484**	**-6.7%**	0.477	-8.0%
North Bay - south	TB6	0.500	**0.469**	**-6.4%**	0.463	-7.6%
North Windmill Cove	TB7	0.511	**0.477**	**-6.7%**	0.470	-7.9%
West Bay - north	TB8	0.363	**0.353**	**-2.9%**	0.351	-3.4%
West Bay - west	TB9	0.327	**0.321**	**-1.7%**	0.320	-2.0%
Eel River	TB10	0.486	**0.472**	**-2.9%**	0.470	-3.4%
Seapuit River	TB11	0.295	**0.293**	**-0.6%**	0.292	-0.8%
Cotuit Bay - north	TB12	0.414	**0.395**	**-4.7%**	0.391	-5.6%
Cotuit Bay - south	TB13	0.321	**0.315**	**-1.9%**	0.314	-2.3%
South Windmill Cove	TB15	0.286	**0.285**	**-0.3%**	0.285	-0.4%
Mellon Cove	TB16	0.402	**0.393**	**-2.4%**	0.391	-2.8%
Dam Pond	TB17	0.392	**0.387**	**-1.2%**	0.386	-1.4%

Scenario Runs 1-3 for the Three Bays Estuary *MEP Technical Team 12-26-07*



Scenario Runs 1-3 for the Three Bays Estuary *MEP Technical Team 12-26-07*

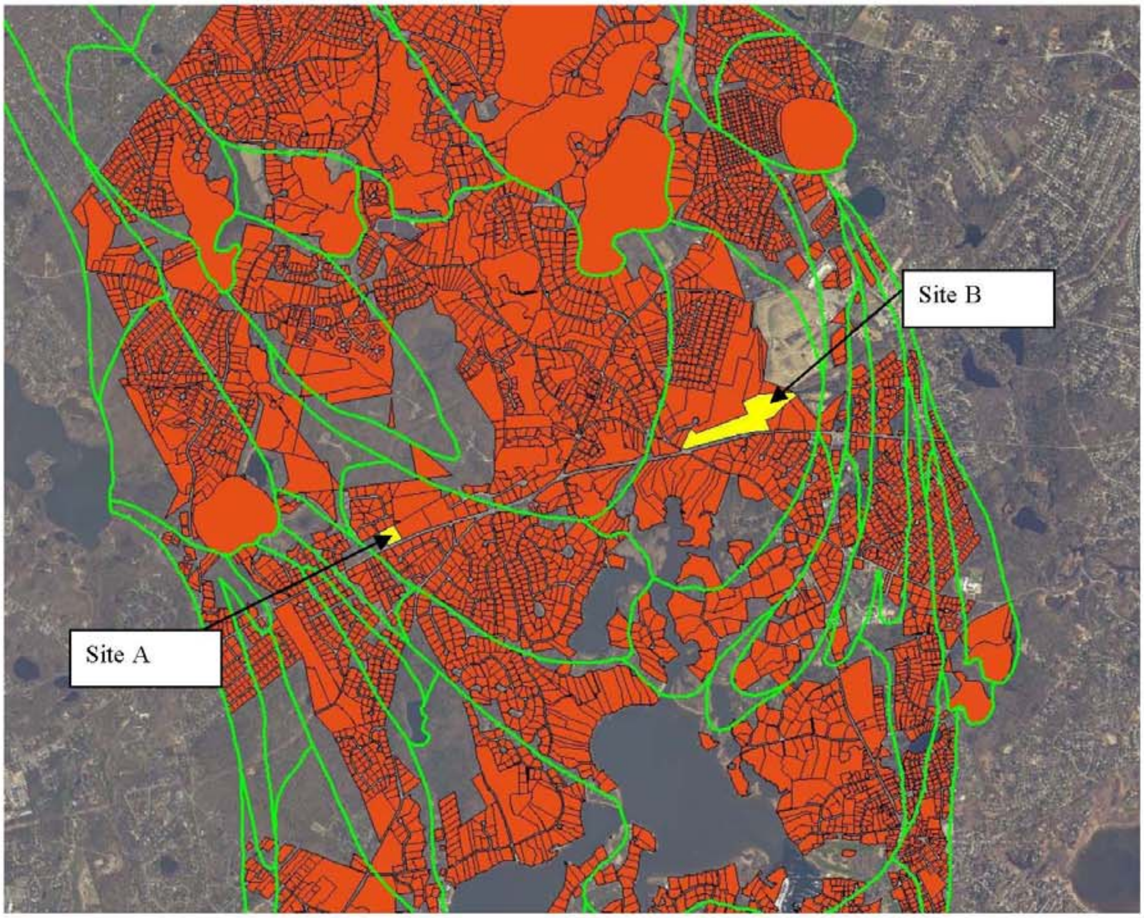


Figure 2. Location of parcels being investigated by the Town of Barnstable as potential disposal sites for treated effluent originating within the Three Bays Watershed. The parcels are shown in yellow and the sub-watersheds to Three Bays are outlined by the green lines.

Scenario Runs 1-3 for the Three Bays Estuary *MEP Technical Team 12-26-07*

Scenario 2: The Nitrogen Load from Title 5 septic systems within selected sub-watersheds to the Three Bays Estuary was to be collected by sewers, treated at a Town WWTF with treated effluent at 5 mg TN L^{-1} undergoing groundwater disposal of at 1 site within the Three Bays watershed.

Scenario 2 is very similar to Scenario 1, with the major difference being the disposal of treated effluent at the single location, Site B, rather than the 2 locations, Sites A and B, used in Scenario 1. The sub-watersheds to Three Bays from the MEP Technical Report[1] are shown in Figure 1, below, and the sub-watersheds with the % of septic systems to be connected to the WWTF(s) are presented in the following table (Table 5). The location of the groundwater disposal site is in the Middle Marstons Mills Sub-watershed, Site B, shown in Figure 2. The effluent was assumed to not alter the sub-watershed boundaries. If the need arises, assessment of effects of effluent disposal on watershed boundaries can be determined by groundwater modeling knowing the volume to be discharged.

Based upon the information in Table 5, the N loading changes from this scenario were developed and are presented in Tables 2 & 6. These new N loads were then processed through the calibrated and validated Linked Watershed-Embayment Model for the Three Bays System to determine changes in the nitrogen levels within the estuarine waters.

Model Output: Three Bays Sentinel Station falls between upper Cotuit Bay (TB-12) and North Bay South (TB-6) in its N level. The target (threshold) TN level at the Sentinel Station is 0.380 mg/L for restoration of this estuary. While Scenario 2 had a showed a greater improvement in water quality within the estuary than did Scenario 1, the TN level within the estuary still remained above the restoration target at Sentinel Station, 0.448 mg/L versus 0.380 mg/L. Similarly, both North Bay stations which should be below 0.400 mg TN L-1, reached 0.477 and 0.463 mg/L, about an 8% decline (Table 7). Similar to Scenario 1, the largest change in estuarine water quality was seen in Prince Cove, Warrens Cove and North Bay. But the TN levels after the proposed wastewater scenario remain unsupportive of healthy infaunal animal habitat in Prince and Warrens Coves (>0.535 mg/L).

Overall, the nitrogen reductions produced by this scenario are insufficient to restore the eelgrass and infaunal animal habitats throughout this estuarine system.

Scenario Runs 1-3 for the Three Bays Estuary *MEP Technical Team 12-26-07*

Table 5 One Treatment Facility (5 mg/l N) And Discharge Area.
Discharge Area "B" located in Middle Marstons Mills LT10

Sub-embayment	Percent Treated and Discharged to Area "B"
Prince Cove LT10	100
North Bay GT10W	100
North Bay LT10	20
Upper Marstons Mills River	100
Prince Cove GT10	5
Lower Marstons Mills River LT10	75
Lower Marstons Mills River GT10	40
Middle Marstons Mills River LT10	80
Bog Pond LT10	60
Bog Pond GT10	90
COMM Davis/Arena/McShane Wells	90
North Bay GT10E	30
Joshua Pond GT10	90
Joshua Pond LT10	60
Micah Pond	95

Table 6. **Scenario 2** sub-embayment and surface water loads used for total nitrogen modeling of the Three Bays system, with total watershed N loads, atmospheric N loads, and benthic flux

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)
Cotuit Bay	21.778	5.786	-50.934
West Bay	18.866	4.233	3.668
Seaptuit River	3.767	0.452	-5.217
North Bay	19.118	3.953	61.587
Prince Cove	5.468	1.230	0.464
Warrens Cove	12.027	-	7.980
Prince Cove Channel	5.537	-	2.107
Marstons Mills Crescent	7.293	-	-
Surface Water Sources			
Marstons Mills River	10.203	-	-
Little River	3.962	-	-

Scenario Runs 1-3 for the Three Bays Estuary *MEP Technical Team 12-26-07*

Table 7. Comparison of model average total N concentrations from present loading and the two loading scenarios, with percent change, for the Three Bays system. Loads are based on atmospheric deposition and a scaled N benthic flux (scaled from present conditions).

Sub-Embayment	monitoring station	present (mg/L)	Scenario 1 (mg/L)	Scenario 1 % change	**Scenario 2 (mg/L)**	**Scenario 2 % change**
Prince Cove - south	TB2	0.695	0.616	-11.3%	**0.584**	**-15.9%**
Prince Cove - north	TB3	0.639	0.578	-9.5%	**0.557**	**-12.7%**
Warrens Cove	TB4	0.595	0.548	-7.9%	**0.535**	**-10.0%**
North Bay - north	TB5	0.518	0.484	-6.7%	**0.477**	**-8.0%**
North Bay - south	TB6	0.500	0.469	-6.4%	**0.463**	**-7.6%**
North Windmill Cove	TB7	0.511	0.477	-6.7%	**0.470**	**-7.9%**
West Bay - north	TB8	0.363	0.353	-2.9%	**0.351**	**-3.4%**
West Bay - west	TB9	0.327	0.321	-1.7%	**0.320**	**-2.0%**
Eel River	TB10	0.486	0.472	-2.9%	**0.470**	**-3.4%**
Seapuit River	TB11	0.295	0.293	-0.6%	**0.292**	**-0.8%**
Cotuit Bay - north	TB12	0.414	0.395	-4.7%	**0.391**	**-5.6%**
Cotuit Bay - south	TB13	0.321	0.315	-1.9%	**0.314**	**-2.3%**
South Windmill Cove	TB15	0.286	0.285	-0.3%	**0.285**	**-0.4%**
Mellon Cove	TB16	0.402	0.393	-2.4%	**0.391**	**-2.8%**
Dam Pond	TB17	0.392	0.387	-1.2%	**0.386**	**-1.4%**

Scenario 3: Determine the Nitrogen Load originating within the watershed to the Three Bays Estuary originating from each of the 3 Towns comprising the contributing area, Barnstable, Mashpee, Sandwich (See provided Table 8).

The results of this partitioning of watershed N loads by municipality is shown in Table 9, below. A complete write-up of this effort was provided under separate cover by the MEP Technical Team (E. Eichner, Cape Cod Commission, 12-7-07). That Technical Memorandum has been reproduced below for the convience of the Pilots Project Team members.

Table 8. Nutrient Sharing between Towns.

Run the amount of nitrogen that is in the Three Bays watershed that originates in Sandwich and Mashpee. Having those numbers will give us a basis to begin to think about nutrient trading with our neighbor towns.

Table 9. Summary of TN loads to the Three Bays watershed (unattenuated) and estuary (attenuated) from each of the 3 municipalities comprising the contributing area, Barnstable, Mashpee and Sandwich.

	N Load (kg/y) Existing Unattenuated				Existing Attenuated				Buildout Unattenuated				Buildout Attenuated			
	BAR	SAN	MAS	TOTAL	BAR	SAN	MAS	TOTAL	BAR	SAN	MAS	TOTAL	BAR	SAN	MAS	TOTAL
Cotuit Bay	10712	1175	134	12020	8971	511	59	9541	12258	1437	240	13935	10087	625	105	10817
West Bay	7185	0	0	7185	6960	0	0	6960	7557	0	0	7557	7328	0	0	7328
Seapuit River	1375	0	0	1375	1375	0	0	1375	1645	0	0	1645	1645	0	0	1645
North Bay	11475	179	20	11673	10648	89	10	10748	12629	219	36	12884	11688	109	18	11815
Prince Cove	4636	882	0	5519	4420	457	0	4877	5190	1134	0	6324	4964	583	0	5547
Warren Cove	21380	7492	0	28872	11051	2370	0	13421	24601	9678	0	34279	12851	3183	0	16034
Prince Cove Channel	2208	0	0	2208	2021	0	0	2021	2600	0	0	2600	2396	0	0	2396
TOTAL	58971	9728	154	68853	45446	3428	69	48943	66481	12468	277	79225	50959	4500	124	55583

Scenario Runs 1-3 for the Three Bays Estuary *MEP Technical Team 12-26-07*

CAPE COD COMMISSION

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MEMORANDUM

TO: Patty Daley, Town of Barnstable, Growth Management Department
Mark Ells, Town of Barnstable, Dept. of Public Works
Dave Mason, Town of Sandwich, Health Department
Tom Fudala, Town of Mashpee, Planning Department

CC: Lindsey Counsell, Three Bays Preservation Society
Brian Howes, SMAST, UMASS Dartmouth
George Zoto, MassDEP
Tom Cambareri, CCC
Paul Niedzwiecki, CCC

FROM: Ed Eichner, Water Scientist

DATE: December 7, 2007

RE: Three Bays watershed town areas and share of TMDL nitrogen loads

In an effort to facilitate discussions among the towns regarding the nitrogen Total Maximum Daily Loads (TMDLs) for Three Bays, the Cape Cod Commission staff have determined the area of each town in the watershed and the nitrogen loading contributions to Three Bays from Barnstable, Sandwich, and Mashpee. A TMDL is required under the federal Clean Water Act for any waters that a state classifies as impaired. The draft TMDL for Three Bays was produced by the Massachusetts Department of Environmental Protection in December 2006. This TMDL is the regulatory ratification of the nitrogen thresholds developed through the Massachusetts Estuaries Project and described in the MEP Three Bays Technical Report (Howes, *et al*., 2005).

Towns with shared watersheds face somewhat complex decisions about what are the fair shares of the nitrogen load allowed under the TMDL and the associated financial responsibilities to remediate impaired water quality. Using separate grants from the federal Environmental Protection Agency, both MassDEP and the Commission have helped to provide information to towns to sort through available information to try to resolve some of the complexities in determining fair shares. Determining town-specific nitrogen loads and watershed areas have been common issues in town discussions for both Popponesset Bay and Pleasant Bay, which are shared by three and four towns, respectively. In order to help move Three Bays discussions forward, the Commission is providing similar watershed-specific information in this memo.

Since the Cape Cod Commission created the MEP watershed nitrogen-loading model, we have the ability to utilize information within the model to determine each town's share of both the unattenuated and attenuated nitrogen loads under both existing and buildout conditions. Attenuated loads are used in the MEP Technical Report analysis to determine the modelled nitrogen concentrations in the Three Bays system and to test the water quality model reliability against data collected by town volunteers.

Using the MEP watershed nitrogen loading model, Commission staff determined that 87% of the 10,882 acre Three Bays watershed is in Barnstable, 13% is in Sandwich, and 1% is in Mashpee (Table 1). In contrast, 93% of the total existing attenuated watershed nitrogen load comes from Barnstable, 7% from Sandwich and <0.5% comes from Mashpee. Under the current buildout scenario, the Barnstable share of the attenuated watershed nitrogen load decreases to 92%, while Sandwich's share rises to 8%. Attenuated loads include all the natural removal of nitrogen by freshwater ponds and streams that is included in the watershed model.

Table 2 presents the TMDLs for each of the seven Three Bays segments and the area of the subwatersheds that contribute nitrogen to each of these segments. The area of each town within the segment subwatershed are also presented. For example, the watershed to Cotuit Bay is 2,110 acres with 90% in Barnstable, 6% in Sandwich, and 4% in Mashpee. These watershed land area percentages are then used to divide up the TMDLs for each of the segments. Figure 1 shows the groupings of the subwatersheds that contribute to the TMDL segments.

Table 3 presents the MEP nitrogen loads by TMDL segment. These loads include existing and buildout scenarios with both unattenuated and attenuated loads. For example, existing attenuated nitrogen loads within the Cotuit Bay subwatershed total 9,541 kilograms per year (kg/y) with 94% from Barnstable, 5% from Sandwich, and 1% from Mashpee. These percentages can be compared to the land area percentages in Table 2 in order to begin discussions about fair shares.

The nitrogen loading results listed in Table 3 will be used by the MEP Technical Team in order to complete some requested scenario runs using funding from MassDEP. These results were completed using funding from the current Management Challenges for Nitrogen Control grant that the Commission has from the US Environmental Protection Agency and represent approximately $2,000 worth of Cape Cod Commission staff time.

I would be glad to discuss these results with you at a mutually agreeable time. These results should help the towns begin further discussions about possible model scenarios runs and fair shares for attaining the TMDLs and remediating water quality in Three Bays.

Table 1. Watershed areas and nitrogen loads by town for the whole Three Bays watershed

Using the Massachusetts Estuaries Project watershed nitrogen-loading model, Cape Cod Commission staff determined the watershed areas and nitrogen loads for the Barnstable, Sandwich, and Mashpee portions of the overall Three Bay watershed. Nitrogen loads are in kilograms per year for existing and buildout scenarios under both unattenuated and attenuated conditions. Nitrogen loads are for watershed sources only and do not include atmospheric deposition on the surface of the estuary.

		Nitrogen Load (kg/y)			
	AREA	Existing		Buildout	
	acres	Unatten	Atten	Unatten	Atten
BAR	9418	58971	45446	66481	50959
SAN	1464	9728	3428	12468	4500
MAS	85	154	69	277	124
TOTAL	10882	68853	48943	79225	55583

%		Nitrogen Load (kg/y)			
	AREA	Existing		Buildout	
		Unatten	Atten	Unatten	Atten
BAR	87%	86%	93%	84%	92%
SAN	13%	14%	7%	16%	8%
MAS	1%	0%	0%	0%	0%
TOTAL	100%	100%	100%	100%	100%

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Table 2. Three Bays TMDL segments: watershed area and TMDL share by town

Using the Massachusetts Estuaries Project watershed nitrogen-loading model, Cape Cod Commission staff determined the watershed areas for the Barnstable, Sandwich, and Mashpee portions to each Total Maximum Daily Load segments. TMDL segments are identified in the MassDEP TMDL document. These daily loads were translated into annual loads and these were used to determine loads per acre of TMDL segment subwatershed. Watershed areas (%) were then also used to determine share of the TMDL segment load within each town.

TMDL Segment	TMDL	Watershed Area (acres)				Watershed area (%)			TMDL		Share of TMDL based on watershed % (kg/y)		
	kg/d	Total	BAR	SAN	MAS	BAR	SAN	MAS	kg/y	kg/ac/y	BAR	SAN	MAS
Cotuit Bay	22.34	2110	1901	134	75	90%	6%	4%	8154	3.86	7346	519	289
West Bay	15.97	664	664			100%			5829	8.78	5829		
Seapuit River	3.77	205	205			100%			1376	6.72	1376		
North Bay	4.47	1381	1351	20	10	98%		1%	1632	1.18	1595		12
Prince Cove	17.89	744	681	64		91%	9%		6530	8.77	5971	559	
Warren Cove	5.05	5484	4270	1214		78%	22%		1843	0.34	1435	408	
Prince Cove Channel	0.77	345	345			100%			281	0.82	281		
TOTAL	70.26	10933	9416	1432	85	93%	6%	1%	25645	2.35	23834	1486	301

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Table 3. Three Bays TMDL segments nitrogen loads

Using the Massachusetts Estuaries Project watershed nitrogen loading model, Cape Cod Commission staff determined the nitrogen loads by town for the each Three Bays TMDL segments under existing and buildout conditions for unattenuated and attenuated loading scenarios. TMDL segments are identified in the MassDEP TMDL document. Nitrogen loads are presented as annual loads and percentage for each town contributing to the segment.

TMDL Segment	N Load (kg/y)															
	Existing Unattenuated				Existing Attenuated				Buildout Unattenuated				Buildout Attenuated			
	BAR	SAN	MAS	TOTAL	BAR	SAN	MAS	TOTAL	BAR	SAN	MAS	TOTAL	BAR	SAN	MAS	TOTAL
Cotuit Bay	10712	1175	134	12020	8971	511	59	9541	12258	1437	240	13935	10087	625	105	10817
West Bay	7185	0	0	7185	6960	0	0	6960	7557	0	0	7557	7328	0	0	7328
Seapuit River	1375	0	0	1375	1375	0	0	1375	1645	0	0	1645	1645	0	0	1645
North Bay	11475	179	20	11673	10648	89	10	10748	12629	219	36	12884	11688	109	18	11815
Prince Cove	4636	882	0	5519	4420	457	0	4877	5190	1134	0	6324	4964	583	0	5547
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Prince Cove Channel	2208	0	0	2208	2021	0	0	2021	2600	0	0	2600	2396	0	0	2396
TOTAL	58971	9728	154	68853	45446	3428	69	48943	66481	12468	277	79225	50959	4500	124	55583

TMDL Segment	N Load (%)															
	Existing Unattenuated				Existing Attenuated				Buildout Unattenuated				Buildout Attenuated			
	BAR	SAN	MAS	TOTAL	BAR	SAN	MAS	TOTAL	BAR	SAN	MAS	TOTAL	BAR	SAN	MAS	TOTAL
Cotuit Bay	89%	10%	1%	100%	94%	5%	1%	100%	88%	10%	2%	100%	93%	6%	1%	100%
West Bay	100%	0%	0%	100%	100%	0%	0%	100%	100%	0%	0%	100%	100%	0%	0%	100%
Seapuit River	100%	0%	0%	100%	100%	0%	0%	100%	100%	0%	0%	100%	100%	0%	0%	100%
North Bay	98%	2%	0%	100%	99%	1%	0%	100%	98%	2%	0%	100%	99%	1%	0%	100%
Prince Cove	84%	16%	0%	100%	91%	9%	0%	100%	82%	18%	0%	100%	89%	11%	0%	100%
Warren Cove	74%	26%	0%	100%	82%	18%	0%	100%	72%	28%	0%	100%	80%	20%	0%	100%
Prince Cove Channel	100%	0%	0%	100%	100%	0%	0%	100%	100%	0%	0%	100%	100%	0%	0%	100%
TOTAL	86%	14%	0%	100%	93%	7%	0%	100%	84%	16%	0%	100%	92%	8%	0%	100%

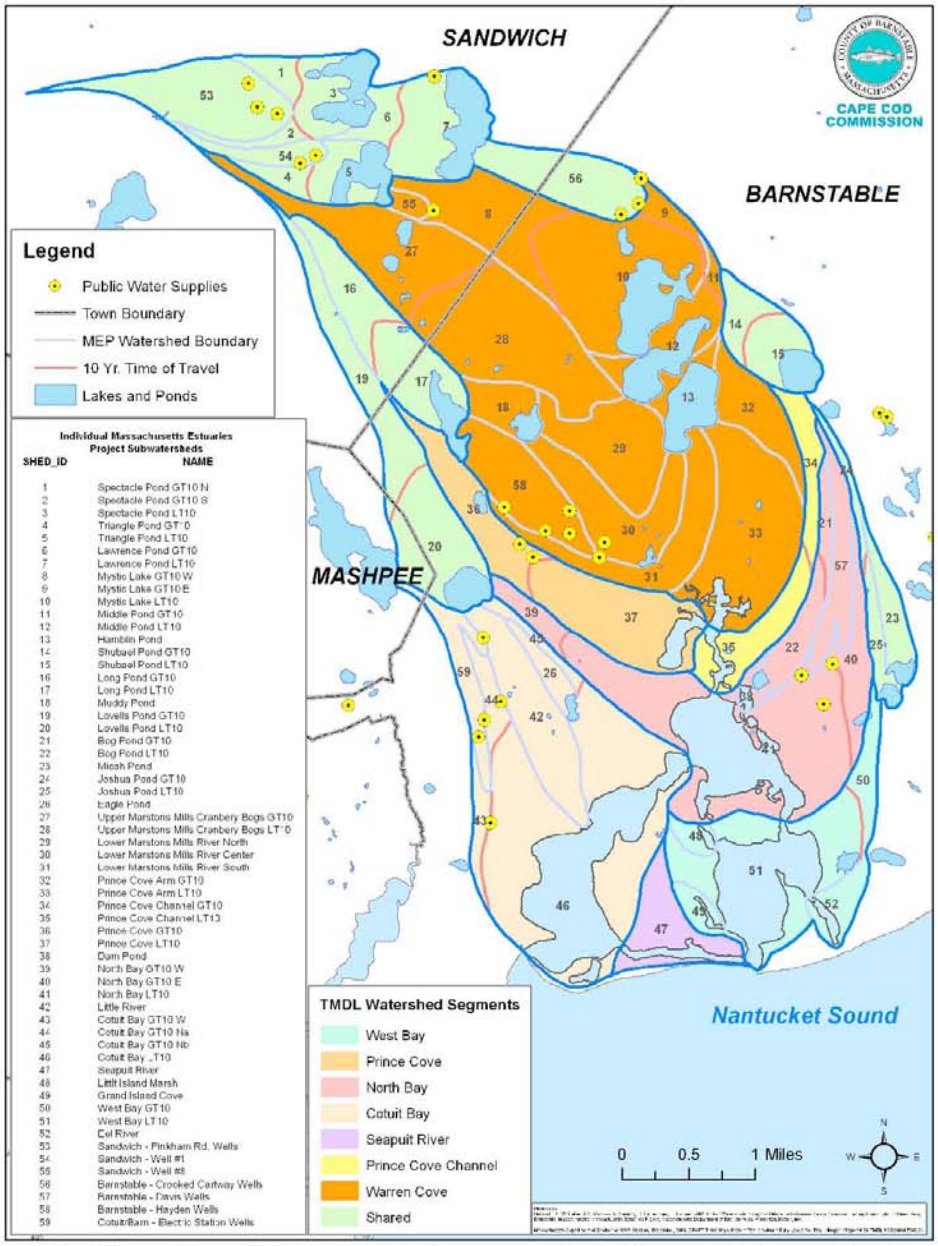

Figure 1. Three Bays Watershed: Subwatersheds Grouped According to TMDL Segment

The Massachusetts Estuaries Project subwatersheds to the Three Bays system are grouped to match the portion of the estuary that has a TMDL. Six TMDLs are assigned to various portions of the Three Bays estuary system.

12/7/07 Cape Cod Commission

SMAST University of Massachusetts Dartmouth The School for Marine Science and Technology

Massachusetts Department of Environmental Protection

Massachusetts Estuaries Project

Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Pleasant Bay System, Towns of Orleans, Chatham, Brewster and Harwich, Massachusetts

Executive Summary

1. Background

This report presents the results generated from the implementation of the Massachusetts Estuaries Project's Linked Watershed-Embayment Approach to the Pleasant Bay embayment system, a coastal embayment situated within the Towns of Chatham, Harwich and Orleans, Massachusetts. Analyses of the Pleasant Bay embayment system was performed to assist the Towns with up-coming nitrogen management decisions associated with current and future wastewater planning efforts, as well as wetland restoration, anadromous fish runs, shell fishery, open-space, and harbor maintenance programs. As part of the MEP approach, habitat assessment was conducted on the embayment based upon available water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure. Nitrogen loading thresholds for use as goals for watershed nitrogen management are the major product of the MEP effort. In this way, the MEP offers a science-based management approach to support the Towns of Chatham, Harwich and Orleans resource planning and decision-making process. The primary products of this effort are: (1) a current quantitative assessment of the nutrient related health of the Pleasant Bay embayment, (2) identification of all nitrogen sources (and their respective N loads) to embayment waters, (3) nitrogen threshold levels for maintaining Massachusetts Water Quality Standards within embayment waters, (4) analysis of watershed nitrogen loading reduction to achieve the N threshold concentrations in embayment waters, and (5) a functional calibrated and validated Linked Watershed-Embayment modeling tool that can be readily used for evaluation of nitrogen management alternatives (to be developed by the Towns) for the restoration of the Pleasant Bay embayment system.

Wastewater Planning: As increasing numbers of people occupy coastal watersheds, the associated coastal waters receive increasing pollutant loads. Coastal embayments throughout the Commonwealth of Massachusetts (and along the U.S. eastern seaboard) are becoming nutrient enriched. The elevated nutrients levels are primarily related to the land use impacts associated with the increasing population within the coastal zone over the past half-century.

The regional effects of both nutrient loading and bacterial contamination span the spectrum from environmental to socio-economic impacts and have direct consequences to the culture, economy, and tax base of Massachusetts's coastal communities. The primary nutrient causing the increasing impairment of our coastal embayments is nitrogen, with its primary sources being wastewater disposal, and nonpoint source runoff that carries nitrogen (e.g. fertilizers) from a range of other sources. Nitrogen related water quality decline represents one of the most serious threats to the ecological health of the nearshore coastal waters. Coastal embayments, because of their shallow nature and large shoreline area, are generally the first coastal systems to show the effect of nutrient pollution from terrestrial sources.

In particular, the Pleasant Bay embayment system within the Towns of Chatham, Harwich and Orleans is at risk of eutrophication (over enrichment) in its upper reaches due to enhanced nitrogen loads entering through groundwater and surface water from the increasingly developed watersheds to this large estuarine system. Eutrophication is a process that occurs naturally and gradually over a period of tens or hundreds of years. However, human-related (anthropogenic) sources of nitrogen may be introduced into ecosystems at an accelerated rate that cannot be easily absorbed, resulting in a phenomenon known as cultural eutrophication. In both marine and freshwater systems, cultural eutrophication results in degraded water quality, adverse impacts to ecosystems, and limits on the use of water resources.

The Towns that exist in the Pleasant Bay watershed (including the Town of Brewster that does not share Pleasant Bay shoreline) have recognized the severity of the problem of eutrophication and the need for watershed nutrient management. By example, the Town of Chatham is currently developing Comprehensive Wastewater Management Plans, which it plans to rapidly implement. The Town of Chatham and Orleans have also completed and implemented wastewater planning in other regions of those Towns that are not associated with the Pleasant Bay embayment system and as such look to integrate restoration of Pleasant Bay with wastewater planning efforts already underway. All of the Towns currently have nutrient management activities related to their tidal embayments, which have been associated with the MEP effort in Pleasant Bay as well as other embayments such as Namskaket marsh, Little Namskaket Marsh, Rock Harbor, Nauset and Nantucket Sound systems such as Saquatucket and Allens Harbors. The Towns and specific work groups have recognized that a rigorous scientific approach yielding site-specific nitrogen loading targets was required for decision-making and alternatives analysis. The completion of this multi-step process has taken place under the programmatic umbrella of the Massachusetts Estuaries Project, which is a partnership effort between all MEP collaborators, the Pleasant Bay Alliance and the Towns. The modeling tools developed as part of this program provide the quantitative information necessary for the Towns' nutrient management groups to predict the impacts on water quality from a variety of proposed management scenarios.

Nitrogen Loading Thresholds and Watershed Nitrogen Management: Realizing the need for scientifically defensible management tools has resulted in a focus on determining the aquatic system's assimilative capacity for nitrogen. The highest-level approach is to directly link the watershed nitrogen inputs with embayment hydrodynamics to produce water quality results that can be validated by water quality monitoring programs. This approach when linked to state-of-the-art habitat assessments yields accurate determination of the "allowable N concentration increase" or "threshold nitrogen concentration". These determined nitrogen concentrations are then directly relatable to the watershed nitrogen loading, which also accounts for the spatial distribution of the nitrogen sources, not just the total load. As such, changes in nitrogen load from differing parts of the embayment watershed can be evaluated relative to the degree to which those load changes drive embayment water column nitrogen concentrations toward the "threshold" for the embayment system. To increase certainty, the "Linked" Model is independently calibrated and validated for each embayment.

Massachusetts Estuaries Project Approach: The Massachusetts Department of Environmental Protection (DEP), the University of Massachusetts – Dartmouth School of Marine Science and Technology (SMAST), and others including the Cape Cod Commission (CCC) have undertaken the task of providing a quantitative tool to communities throughout southeastern Massachusetts (the Linked Watershed-Embayment Management Model) for nutrient management in their coastal embayment systems. Ultimately, use of the Linked Watershed-Embayment Management Model tool by municipalities in the region results in effective screening of nitrogen reduction approaches and eventual restoration and protection of valuable coastal resources. The MEP provides technical guidance in support of policies on nitrogen loading to embayments, wastewater management decisions, and establishment of nitrogen Total Maximum Daily Loads (TMDLs). A TMDL represents the greatest amount of a pollutant that a waterbody can accept and still meet water quality standards for protecting public health and maintaining the designated beneficial uses of those waters for drinking, swimming, recreation and fishing. The MEP modeling approach assesses available options for meeting selected nitrogen goals that are protective of embayment health and achieve water quality standards.

The core of the Massachusetts Estuaries Project analytical method is the Linked Watershed-Embayment Management Modeling Approach, which links watershed inputs with embayment circulation and nitrogen characteristics.

The Linked Model builds on well-accepted basic watershed nitrogen loading approaches such as those used in the Buzzards Bay Project, the CCC models, and other relevant models. However, the Linked Model differs from other nitrogen management models in that it:

- requires site-specific measurements within each watershed and embayment;
- uses realistic "best-estimates" of nitrogen loads from each land-use (as opposed to loads with built-in "safety factors" like Title 5 design loads);
- spatially distributes the watershed nitrogen loading to the embayment;
- accounts for nitrogen attenuation during transport to the embayment;
- includes a 2D or 3D embayment circulation model depending on embayment structure;
- accounts for basin structure, tidal variations, and dispersion within the embayment;
- includes nitrogen regenerated within the embayment;
- is validated by both independent hydrodynamic, nitrogen concentration, and ecological data;
- is calibrated and validated with field data prior to generation of "what if" scenarios.

The Linked Model Approach's greatest assets are its ability to be clearly calibrated and validated, and its utility as a management tool for testing "what if" scenarios for evaluating watershed nitrogen management options.

For a comprehensive description of the Linked Model, please refer to the *Full Report: Nitrogen Modeling to Support Watershed Management: Comparison of Approaches and Sensitivity Analysis*, available for download at http://www.state.ma.us/dep/smerp/smerp.htm. A more basic discussion of the Linked Model is also provided in Appendix F of the *Massachusetts*

Estuaries Project Embayment Restoration Guidance for Implementation Strategies, available for download at http://www.state.ma.us/dep/smerp/smerp.htm. The Linked Model suggests which management solutions will adequately protect or restore embayment water quality by enabling towns to test specific management scenarios and weigh the resulting water quality impact against the cost of that approach. In addition to the management scenarios modeled for this report, the Linked Model can be used to evaluate additional management scenarios and may be updated to reflect future changes in land-use within an embayment watershed or changing embayment characteristics. In addition, since the Model uses a holistic approach (the entire watershed, embayment and tidal source waters), it can be used to evaluate all projects as they relate directly or indirectly to water quality conditions within its geographic boundaries. Unlike many approaches, the Linked Model accounts for nutrient sources, attenuation, and recycling and variations in tidal hydrodynamics and accommodates the spatial distribution of these processes. For an overview of several management scenarios that may be employed to restore embayment water quality, see *Massachusetts Estuaries Project Embayment Restoration Guidance for Implementation Strategies*, available for download at http://www.state.ma.us/dep/smerp/smerp.htm.

Application of MEP Approach: The Linked Model was applied to the Pleasant Bay embayment system by using site-specific data collected by the MEP and water quality data from the Chatham WaterWatchers, the Orleans and the Pleasant Bay Alliance Water Quality Monitoring Programs (see Chapter 2). Evaluation of upland nitrogen loading was conducted by the MEP, data was provided by the Planning Departments in each of the Towns, and watershed boundaries delineated by USGS. This land-use data was used to determine watershed nitrogen loads within the Pleasant Bay embayment system and each systems sub-embayments (current and build-out loads are summarized in Chapter IV). Water quality within a sub-embayment is the integration of nitrogen loads with the site-specific estuarine circulation. Therefore, water quality modeling of this tidally influenced estuary included a thorough evaluation of the hydrodynamics of the estuarine system. Estuarine hydrodynamics control a variety of coastal processes including tidal flushing, pollutant dispersion, tidal currents, sedimentation, erosion, and water levels. Once the hydrodynamics of the system was quantified, transport of nitrogen was evaluated from tidal current information developed by the numerical models.

A two-dimensional depth-averaged hydrodynamic model based upon the tidal currents and water elevations was employed for the Pleasant Bay embayment system. Once the hydrodynamic properties of the estuarine system was computed, two-dimensional water quality model simulations were used to predict the dispersion of the nitrogen at current loading rates. Using standard dispersion relationships for estuarine systems of this type, the water quality model and the hydrodynamic model was then integrated in order to generate estimates regarding the spread of bio-available and total nitrogen from the site-specific hydrodynamic properties. The distributions of nitrogen loads from watershed sources were determined from land-use analysis while nitrogen entering the coastal embayment was quantified by direct measurement of stream nutrient concentrations and freshwater flow, predominantly groundwater, in streams discharging directly to the embayment. Boundary nutrient concentrations in the Atlantic Ocean source waters were taken from water quality monitoring data. Measurements of current salinity distributions throughout the estuarine waters of the Pleasant Bay embayment system was used to calibrate the water quality model, with validation using measured nitrogen concentrations (under existing loading conditions). The underlying hydrodynamic model was calibrated and validated independently using water elevations measured in time series throughout the embayments.

MEP Nitrogen Thresholds Analysis: The threshold nitrogen level for an embayment represents the average water column concentration of nitrogen that will support the habitat quality being sought. The water column nitrogen level is ultimately controlled by the watershed nitrogen load and the nitrogen concentration in the inflowing tidal waters (boundary condition). The water column nitrogen concentration is modified by the extent of sediment regeneration. Threshold nitrogen levels for the embayment systems in this study were developed to restore or maintain SA waters or high habitat quality. High habitat quality was defined as supportive of eelgrass and infaunal communities. Dissolved oxygen and chlorophyll a were also considered in the assessment.

The approach for determining nitrogen loading rates, which will maintain acceptable habitat quality throughout and embayment system, is to first identify a sentinel location within the embayment and second to determine the nitrogen concentration within the water column which will restore that location to the desired habitat quality (threshold nitrogen level). The sentinel location is selected such that the restoration of that one site will necessarily bring the other regions of the system to acceptable habitat quality levels. Once the sentinel site and its target nitrogen level are determined, the Linked Watershed-Embayment Model is used to adjust nitrogen loads sequentially until the targeted nitrogen concentration is achieved. For the Pleasant Bay System, the restoration target should reflect both recent pre-degradation habitat quality and be reasonably achievable. The load reductions presented in the report represent only one of a suite of potential reduction approaches that need to be evaluated by the community. The presentation in this report of load reductions aims to establish the general degree and spatial pattern of reduction that will be required for restoration of this nitrogen impaired embayment.

The Massachusetts Estuaries Project's thresholds analysis, as presented in this technical report, provides the site-specific nitrogen reduction guidelines for nitrogen management of the Pleasant Bay embayment system. Future water quality modeling scenarios should be run which incorporate the spectrum of strategies that result in nitrogen loading reduction to the embayment. These scenarios should be developed in coordination with all the Towns in the Pleasant Bay watershed in order to effectively examine the effect of load reductions on water column nutrient concentrations. The MEP analysis has initially focused upon nitrogen loads from on-site septic systems as a test of the potential for achieving the level of total nitrogen reduction for restoration of each embayment system. The concept was that since septic system nitrogen loads generally represent 70%-80% of the controllable watershed load to the Pleasant Bay embayment system and are more manageable than other of the nitrogen sources, the ability to achieve needed reductions through this source is a good gauge of the feasibility for restoration of these systems.

2. Problem Assessment (Current Conditions)

A habitat assessment was conducted throughout Pleasant Bay based upon available water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure. The Pleasant Bay System is comprised of a variety of basins showing a range of habitat health form "Healthy" (supportive of eelgrass, infaunal communities and with little oxygen stress) to "Degraded" (absence of eelgrass and benthic animals and periodic hypoxia/anoxia). There appears to be a clear relationship between habitat quality and the level of nitrogen enrichment. The less well flushed enclosed basins tend to be focal points for watershed nitrogen inputs and have relatively lower tidal flushing rates and greater habitat impairment. In contrast, the larger basins and areas near the tidal inlet have a range in habitat quality, Moderately Impaired to Healthy, related to their flushing rate and depth.

The spatial distribution of habitat quality among the Pleasant Bay sub-embayments shows significant spatial variation, typical of other embayments within the MEP region. Although there are a large number of sub-embayments to the Pleasant Bay System, the habitat health or impairment associated with each of the key indicators (oxygen/chlorophyll a, eelgrass, infauna communities) tends to follow the 4 classifications listed below based upon the basin type:

(A) small enclosed basin (Meetinghouse Pond, Lonnies Pond, Areys Pond, Round Cove, Quanset Pond, Paw Wah Pond, Upper Muddy Creek),
(B) moderate sized tributary sub-embayment (The River, Muddy Creek),
(C) salt marsh dominated tidal sub-estuary (Pochet),
(D) large lagoonal estuarine basin (Little Pleasant Bay, Pleasant Bay, Chatham Harbor).

The underlying quantitative data is presented on nitrogen (Section VI.1.3), oxygen and chlorophyll *a* (Section VII.2), eelgrass (Section VII.3), and benthic infauna (Section VII.4).

The effect of nitrogen enrichment is to cause oxygen depletion; however, with increased phytoplankton (or epibenthic algae) production, oxygen levels will rise in daylight to above atmospheric equilibration levels in shallow systems (generally ~7-8 mg L^{-1} at the mooring sites). The clear evidence of oxygen levels above atmospheric equilibration indicates that the upper tidal reaches of the Pleasant Bay System (particularly in the terminal sub-embayments are eutrophic.

The extent of oxygen related stress among the Pleasant Bay sub-embayments showed significant spatial variation, typical of other embayments within the MEP region. Although there are a large number of sub-embayments to the Pleasant Bay System, the habitat impairment associated with oxygen depletion tended to follow the 4 groups mentioned above.

The general pattern is for a high level of oxygen stress (frequent hypoxia or anoxia) in the bottomwaters of the small enclosed basins (group A) which tend to have higher nitrogen levels and high rates of sediment metabolism, associated with their circulation and focus of watershed nitrogen loads. The Meetinghouse Pond basin and outlet channel, Lonnies Pond and its outlet channel, the Areys Pond outlet channel (Namequoit River), Quanset Pond all showed significant levels of oxygen depletion were routinely hypoxic and except for Quanset Pond levels were frequently <2 mg/L. In the same group of enclosed basins, Areys Pond, Paw Wah Pond and upper Muddy Creek showed frequent anoxia (absence of oxygen). Among the enclosed basins only Round Cove showed only mild hypoxia with levels above 4 mg/L and generally above 5 mg/L during the full deployment.

In contrast, the salt marsh dominated tidal creek of Pochet (group C) showed frequent oxygen depletions to 3-4 mg/L, but was generally above 4 mg/L. The oxygen conditions in Pochet creek are consistent with the biogeochemistry of salt marshes. Salt marsh creeks (that do not empty at low tide) frequently become hypoxic in summer as a result of the high organic matter loading associated with marshes. Even pristine salt marshes can exhibit this behavior.

The large main basins of the lagoonal estuarine component (group D) showed oxygen conditions consistent with their rates of sediment metabolism associated with their deep waters and depositional nature (Little Pleasant Bay, Pleasant Bay) or their high tidal velocities (Chatham Harbor and eastern channel form Chatham Harbor to Little Pleasant Bay, channel between Strong Island and Bassing Harbor). The Upper Pleasant Bay at Namequoit Point showed oxygen levels frequently declining to 4-5 mg/L and the western most basin of Pleasant Bay (between Round Cove and Muddy Creek) had a single event to 2-4 mg/L, although was generally >5 mg/L. Approaching Chatham Harbor oxygen conditions improved (see Strong Island results), with oxygen conditions generally >6 mg/L with short declines to 5 mg/L associated with the outflow of lower oxygen waters from Pleasant Bay.

At present, eelgrass is present within large portions of the Pleasant Bay System, indicative of a system with high habitat quality areas. These eelgrass beds are generally restricted to the larger lagoonal basins, Little Pleasant Bay, Pleasant Bay and Chatham Harbor. There are also smaller eelgrass areas in Pochet and fringing shallow areas in The River and Meetinghouse Pond. The only tributary embayment to Pleasant Bay with significant eelgrass habitat is Bassing Harbor. The basins presently supporting eelgrass habitat also supported habitat in the 1951 historical analysis. However, it is clear from the 1951, 1995 and 2001 temporal sequence that the eelgrass areas in each basin, except Chatham Harbor, are declining in coverage. In The River and Pochet the eelgrass areas were always patchy and in the shallows. By the 2001 survey this pattern continues, but the beds appear to be declining, although they persist.

Virtually all of the small enclosed basins (group A) did not appear to support eelgrass historically and do not support it today, with the exception of the small patch in the shallows of Meetinghouse Pond and in lower Muddy Creek. The general pattern is consistent with the deeper waters of these basins and their location and structure which tends to result in nitrogen enrichment.

The overall pattern of eelgrass distribution and temporal decline in coverage fully consistent with the spatial pattern of nitrogen enrichment (Chapter VI) and oxygen and chlorophyll levels in the various basins (see above). The pattern of decline is typical of environmental changes wrought by nutrient enrichment. It is possible to determine a general idea of short- and long-term rates of change in eelgrass coverage from the mapping data, although there are only 3 surveys. Over the 50 year period1951-2001 the Pleasant Bay System has lost ~583 acres of eelgrass habitat. Interestingly, the rate of loss has been relatively constant at ~11 acres per year. This loss has occurred as watershed nitrogen loading rates gradually increased several fold due to changes in land use within the Pleasant Bay watershed

The Infauna Study indicated that as for the oxygen and chlorophyll indicators and the distribution of sediment metabolism, the enclosed basins (group A, above) are generally significantly to severely impaired relative to benthic infaunal habitat quality. Among the enclosed basins, all were at least significantly impaired. Paw Wah Pond is virtually devoid of benthic animals (only 1-4 individuals per sample) as would be expected from its high level of oxygen stress. Similarly, Areys Pond, Quanset Pond, Upper Muddy Creek supported significantly depleted benthic animal populations, consistent with their nitrogen related oxygen stress. The other enclosed basins were able to support benthic infauna, but the community was dominated by opportunistic species indicative of very high organic matter loading (Lonnies Pond, Meetinghouse Pond outlet channel) or by intermediate stress indicators. The dominance of these intermediate indicators in The River, Round Cove, Meetinghouse Pond suggests that these systems, which also showed only moderate oxygen stress, are only moderately beyond their nitrogen loading limits (Chapter VII).

The larger lagoonal basins of Little Pleasant Bay generally supported infaunal communities indicative of a moderate level of stress from organic matter loading and oxygen depletion. However, the pattern was for a decrease in habitat quality moving from the marginal to depths. This pattern is typical of a system near, but beyond its nitrogen loading limit, where organic matter deposition in the deep basin areas is the proximate cause of the impairment of benthic habitat quality. Chatham Harbor habitat supported only moderate numbers of individuals and species, but this appeared to result from the dynamic nature of the bottom sediments (unstable bottom), due to the high tidal velocities, rather than nutrient related impairment.

3. Conclusions of the Analysis

The threshold nitrogen level for an embayment represents the average watercolumn concentration of nitrogen that will support the habitat quality being sought. The watercolumn nitrogen level is ultimately controlled by the integration of the watershed nitrogen load, the nitrogen concentration in the inflowing tidal waters (boundary condition) and dilution and flushing via tidal flows. The water column nitrogen concentration is modified by the extent of sediment regeneration and by direct atmospheric deposition.

Threshold nitrogen levels for each of the sub-embayment systems in this study were developed to restore or maintain SA waters or high habitat quality. In these systems, high habitat quality was defined as supportive of eelgrass and diverse benthic benthos animal communities. Dissolved oxygen and chlorophyll *a* were also considered in the assessment.

Watershed nitrogen loads (Tables ES-1 and ES-2) for the Pleasant Bay embayment system was comprised primarily of wastewater nitrogen. Land-use and wastewater analysis found that generally about 70%-80% of the controllable watershed nitrogen load to the embayment was from wastewater.

Based upon the significant historical and present eelgrass habitat within the Pleasant Bay System, 2400 acres and 1800 acres respectively (Chapter VII), eelgrass was selected as the target for the development of the site-specific nitrogen threshold. In addition, a secondary threshold supportive of benthic animal communities (infauna) was developed in areas that do not have documented eelgrass habitat. The eelgrass threshold applies to the sentinel station (and secondary eelgrass station in Ryders Cove) and the secondary "check" thresholds for infauna habitat is for the smaller sub-basins not naturally supportive of eelgrass based on historical records.

The MEP's previous analysis of Bassing Harbor found very high levels of dissolved organic nitrogen within the embayment's waters (based upon data from the Chatham and Pleasant Bay Alliance Water Quality Monitoring Programs). While some portion of the dissolved organic nitrogen is actively cycling, the vast majority is refractory (non-biologically active) within the timeframe of the flushing of the Pleasant Bay System. The result is that the dissolved organic nitrogen presents a large non-active pool generally separate from the nitrogen fractions active in eutrophication (i.e. ammonium and nitrate+nitrite, particulate organic nitrogen). The biologically active nitrogen pools are represented by the species directly available to phytoplankton and algae (plant available nitrogen), ammonium and nitrate+nitrite, and the particulate organic nitrogen comprised primarily of phytoplankton (live and dead). Together this nitrogen group is termed bioactive nitrogen. Given the large dissolved organic nitrogen pool within Pleasant Bay the MEP Technical Team adopted the same approach used previously for the TMDL analysis of Bassing Harbor. The threshold was developed based upon the bioactive nitrogen pool, which appears to be relatively consistent between embayments both within and outside of Pleasant Bay, and then the bioactive threshold was transformed to the total nitrogen level by adding back in the dissolved organic nitrogen concentration derived for the site from direct measurements.

The threshold nitrogen levels for the Pleasant Bay embayment system in the Towns of Brewster, Chatham, Harwich and Orleans were determined as follows:

Pleasant Bay Threshold Nitrogen Concentrations

- While there is significant variation in the dissolved organic nitrogen levels, hence total nitrogen levels supportive of healthy eelgrass habitat, the level of bioactive nitrogen supportive of this habitat appears to be relatively constant. Therefore, the MEP Technical Team set a single eelgrass threshold based upon stable eelgrass beds, tidally averaged bioactive N levels and the stability of eelgrass as depicted in coverages from 1951-2001. The eelgrass threshold was set at 0.16 mg bioactive N/L based upon the Chatham (Dec 2003 MEP report) analysis for Bassing Harbor. That report for Bassing Harbor indicated a bioactive level for high quality eelgrass habitat of 0.160 mg bioactive N/L based upon Healthy eelgrass community in both Bassing Harbor at 0.135 bioactive N/L and in Stage Harbor at 0.160 bioactive N/L (Oyster River Mouth). The higher value was used as the eelgrass habitat in Bassing Harbor was below its nitrogen loading limit at that time. Taking into consideration the analysis of the Pleasant Bay System, the bioactive nitrogen threshold of 0.160 mg N/L yields an equivalent Total Nitrogen Threshold for the Bassing Harbor Sub-embayment (average upper and lower Ryders Cove stations) of 0.523 mg N L^{-1}. This value is very close to the previous Bassing Harbor specific threshold range of 0.527-0.552 mg N L^{-1}. The slight shift in threshold level results from the greatly expanded water quality database for the present versus previous analysis. The nitrogen boundary condition (concentration of N in inflowing tidal waters from Pleasant Bay) for the Bassing Harbor System is 0.45 mg N L^{-1}.

- The sentinel station for the Pleasant Bay System based on a nitrogen threshold targeting restoration of eelgrass was placed within the uppermost reach of Little Pleasant Bay (PBA-12) near the inlets to The River and Pochet. The threshold bioactive nitrogen level at this site (as for Ryders Cove) is 0.160 mg bioactive N L^{-1}. Based upon the background dissolved organic nitrogen average of upper Little Pleasant Bay and Lower Pochet 0.563 mg N L^{-1} and the bioactive threshold value, the total nitrogen level at the sentinel station (PBA-12) is 0.723 mg N L^{-1}. The restoration goal is to improve the eelgrass habitat throughout Little Pleasant Bay and the historic distribution in Pleasant Bay, which will see lower nitrogen levels when the threshold is reached. In addition, the fringing eelgrass beds within The River and within Pochet should also be restored, as they are in shallower water than the nearby sentinel site and therefore are able to tolerate slightly higher watercolumn nitrogen levels. Moreover, the same threshold bioactive nitrogen level should be met for the previous sentinel station (upper Ryders Cove) in Bassing Harbor System when levels are achieved at the sentinel station in upper Little Pleasant Bay. However, given the partial independence of the Bassing Harbor sub-embayment system relative to the greater Pleasant Bay System (i.e. its own local watershed nitrogen load plays a critical role in its health), the upper Ryders Cove sentinel station should be maintained as the guide for this sub-embayment to Pleasant Bay. It should also be noted that while the bioactive threshold is the same at both sites, the Total Nitrogen level in Ryders Cove is 0.523 mg N L^{-1}, due to the lower dissolved organic nitrogen levels in the lower Bay.

- While eelgrass restoration is primary nitrogen management goal within the Pleasant Bay System, there are small basins which do not appear to have historically (1951) supported eelgrass habitat. For these sub-embayments, restoration and maintenance of healthy animal communities is the management goal. At present, moderately impaired infaunal communities are present in Ryders Cove (PBA-03) at tidally averaged bioactive nitrogen levels of 0.244 mg N L^{-1}. Similarly, there are moderately impaired infaunal communities, designated primarily by the dominance of amphipods (amphipod mats) in most of the 8 sub-embayments of focus. These communities are present adjacent the inlet to Lonnies Pond (in The River Upper) at bioactive nitrogen levels of 0.217 mg N L^{-1}, in the Namequoit River at 0.216-0.239 mg N L^{-1} and in Round Cove at mg N L^{-1} at 0.239 mg N L^{-1}. These communities can be found at even higher levels in the fringing shallow areas of deep basins like Areys Pond (0.299 mg N L^{-1}) and Meetinghouse Pond (0.411 mg N L^{-1}). Very shallow waters tend to minimize oxygen depletion that severely stress infaunal communities in deeper basins. Paw Wah Pond is periodically hypoxic and as a result does not presently support infaunal habitat. These data are at higher bioactive nitrogen levels than the healthy infaunal habitat in the lower Pochet Basin (WMO-03) at 0.178 mg N L^{-1}. It appears that the infaunal threshold lies between 0.18 and 0.22 mg N L^{-1} tidally averaged bioactive nitrogen. Based upon the animal community and nitrogen analysis discussed in Chapter VIII, the restoration goal for the 8 small tributary sub-basin systems to Pleasant Bay is to restore a healthy habitat to the full basin in the shallower or more open waters and to the margins in the deep drowned kettles that periodically stratify. This would argue for a bioactive nitrogen threshold of 0.21 mg N L-1, lower than the lowest station with significant amphipod presence. Translation to Total Nitrogen is presented in detail in Chapter VIII.

- Development of nitrogen load reductions needed to meet the threshold concentration of 0.16 mg/l bioactive nitrogen (DIN+PON) in Ryders Cove (the average of PBA-03 and CM-13) and Upper Little Pleasant Bay (PBA-13) focused primarily on septic load removal within the River and Bassing Harbor systems. Due to the relatively large size of the Pleasant Bay system, achieving the primary threshold concentration for the restoration of eelgrass at the sentinel stations alone did not achieve the secondary threshold at the series of small embayments surrounding Pleasant and Little Pleasant Bays. The secondary threshold concentration of 0.21 mg/l bioactive nitrogen (DIN+PON) in Meetinghouse Pond (Outer), Lonnies Pond, Upper Namequoit River, Upper Pochet, Paw Wah Pond, Little Quanset Pound, Round Cove and Lower Muddy Creek required site-specific removal of septic nitrogen from the watersheds directly impacting these sub-embayments. Chapter VIII presents the percent of septic load removed from the various watersheds to achieve both the primary and secondary threshold concentrations of bioactive nitrogen at the sentinel stations

It is important to note that the analysis of future nitrogen loading to the Pleasant Bay estuarine system focuses upon additional shifts in land-use from forest/grasslands to residential and commercial development. However, the MEP analysis indicates that significant increases in nitrogen loading can occur under present land-uses, due to shifts in occupancy, shifts from seasonal to year-round useage and increasing use of fertilizers (presently less than half of the parcels use lawn fertilizers). Therefore, watershed-estuarine nitrogen management must include management approaches to prevent increased nitrogen loading from both shifts in land-uses (new sources) and from loading increases of current land-uses. The overarching conclusion of the MEP analysis of the Pleasant Bay estuarine system is that restoration will necessitate a reduction in the present nitrogen inputs and management options to negate additional future nitrogen inputs.

Table ES-1a. Existing total and sub-embayment nitrogen loads to the estuarine waters of the Pleasant Bay system, observed nitrogen concentrations, and sentinel system threshold nitrogen concentrations. Loads to estuarine waters of Pleasant Bay include both upper watershed regions contributing to major surface water inputs.

Sub-embayments	Natural Background Watershed Load [1] (kg/day)	Present Land Use Load [2] (kg/day)	Present Septic System Load (kg/day)	Present Watershed Load [4] (kg/day)	Direct Atmospheric Deposition [5] (kg/day)	Present Net Benthic Flux (kg/day)	Present Total Load [6] (kg/day)	Observed TN Conc. [7] (mg/L)	Observed Bioactive N Conc. [7] (mg/L)	Threshold Bioactive N Conc. (mg/L)
PLEASANT BAY SYSTEM										
Meetinghouse Pond	0.693	1.058	5.140	6.197	0.584	14.365	21.146	0.72-0.98	0.28-0.41	
The River – upper	0.526	0.701	2.071	2.773	0.288	6.263	9.324	0.85-0.86	0.22-0.25	0.200[8]
The River – lower	0.756	1.008	2.871	3.879	2.241	10.480	16.600	0.56	0.18	0.160[8]
Lonnies Pond	0.682	0.811	1.630	2.441	0.225	1.591	4.257	0.78	0.28	0.200[8]
Areys Pond	0.468	0.526	0.778	1.304	0.181	5.996	7.480	0.73	0.30	
Namequoit River	0.562	0.726	2.011	2.737	0.523	14.570	17.830	0.73-0.83	0.24-0.30	0.200[8]
Paw Wah Pond	0.233	0.351	1.510	1.860	0.082	3.630	5.572	0.71	0.27	0.200[8]
Pochet Neck	1.233	1.808	6.614	8.422	1.767	-0.791	9.398	0.72-0.78	0.24-0.28	0.200[8]
Little Pleasant Bay	1.660	3.148	4.986	8.134	24.086	37.226	69.446	0.57-0.77	0.14-0.18	
Quanset Pond	0.296	0.378	1.403	1.781	0.170	5.988	7.939	0.56-0.60	0.19-0.21	0.200[8]

[1] assumes entire watershed is forested (i.e., no anthropogenic sources)
[2] composed of non-wastewater loads, e.g. fertilizer and runoff and natural surfaces and atmospheric deposition to lakes
[3] existing wastewater treatment facility discharges to groundwater
[4] composed of combined natural background, fertilizer, runoff, and septic system loadings
[5] atmospheric deposition to embayment surface only
[6] composed of natural background, fertilizer, runoff, septic system atmospheric deposition and benthic flux loadings
[7] average of 2000 – 2005 data, ranges show the upper to lower regions (highest-lowest) of an sub-embayment.
[8] Threshold for sentinel sites correspond to monitoring station locations: The River (upper) WMO-10, The River (mouth) PBA-13, Lonnies Pond PBA-15, Namequoit River WMO-06, Paw Wah Pond PBA-11, Pochet Neck WMO-05, Quanset Pond WMO-12, Round Cove PBA-09, Muddy Creek PBA-05, Ryder Cove PBA-13 and CM-13.

Table ES-1b. Existing total and sub-embayment nitrogen loads to the estuarine waters of the Pleasant Bay system, observed nitrogen concentrations, and sentinel system threshold nitrogen concentrations. Loads to estuarine waters of Pleasant Bay include both upper watershed regions contributing to major surface water inputs.

Sub-embayments	Natural Background Watershed Load [1] (kg/day)	Present Land Use Load [2] (kg/day)	Present Septic System Load (kg/day)	Present Watershed Load [4] (kg/day)	Direct Atmospheric Deposition [5] (kg/day)	Present Net Benthic Flux (kg/day)	Present Total Load [6] (kg/day)	Observed TN Conc. [7] (mg/L)	Observed Bioactive N Conc. [7] (mg/L)	Threshold Bioactive N Conc. (mg/L)
PLEASANT BAY SYSTEM										
Round Cove	0.603	1.063	3.162	4.225	0.170	8.416	12.811	0.71	0.25	0.200[8]
Muddy Creek - upper	1.951	2.825	7.156	9.981	0.162	4.560	14.702	1.26	0.70	
Muddy Creek - lower	1.471	2.137	6.340	8.477	0.205	-1.226	7.457	0.57	0.24	0.200[8]
Pleasant Bay	3.808	14.408	14.874	29.282	37.005	108.821	175.108	0.44-0.73	0.14-0.19	
Bassing Harbor - Ryder Cove	2.003	2.682	7.137	9.819	1.296	9.356	20.471	0.42-0.72	0.16-0.25	0.160[8]
Bassing Harbor - Frost Fish Creek	0.400	0.704	2.200	2.904	0.096	-0.154	2.846	1.16	0.35	
Bassing Harbor - Crows Pond	0.534	0.893	3.326	4.219	1.389	0.612	6.220	0.84	0.21	
Bassing Harbor	0.233	0.268	1.400	1.668	1.071	-4.976	-2.237	0.49	0.12	
Chatham Harbor	1.838	2.904	14.195	17.099	14.153	-40.208	-8.956	0.35-0.43	0.10-0.11	
Pleasant Bay System Total	**19.951**	**38.400**	**88.803**	**127.203**	**85.693**	**184.519**	**397.415**	**0.35-1.26**	**0.10-0.70**	**0.160[8]**

1 assumes entire watershed is forested (i.e., no anthropogenic sources)
2 composed of non-wastewater loads, e.g. fertilizer and runoff and natural surfaces and atmospheric deposition to lakes
3 existing wastewater treatment facility discharges to groundwater
4 composed of combined natural background, fertilizer, runoff, and septic system loadings
5 atmospheric deposition to embayment surface only
6 composed of natural background, fertilizer, runoff, septic system atmospheric deposition and benthic flux loadings
7 average of 2000 – 2005 data, ranges show the upper to lower regions (highest-lowest) of an sub-embayment.
8 Threshold for sentinel sites correspond to monitoring station locations: The River (upper) WMO-10, The River (mouth) PBA-13, Lonnies Pond PBA-15, Namequoit River WMO-06, Paw Wah Pond PBA-11, Pochet Neck WMO-05, Quanset Pond WMO-12, Round Cove PBA-09, Muddy Creek PBA-05, Ryder Cove PBA-13 and CM-13.

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Table ES-2a. Present Watershed Loads, Thresholds Loads, and the percent reductions necessary to achieve the threshold concentrations identified for the Pleasant Bay system.

Sub-embayments	Present Watershed Load [1] (kg/day)	Target Threshold Watershed Load [2] (kg/day)	Direct Atmospheric Deposition (kg/day)	Benthic Flux Net [3] (kg/day)	Percent watershed reductions needed to achieve threshold load levels
PLEASANT BAY SYSTEM					
Meetinghouse Pond	6.197	1.058	0.584	7.857	-82.9%
The River - upper	2.773	1.737	0.288	4.102	-37.4%
The River - lower	3.879	2.444	2.241	8.517	-37.0%
Lonnies Pond	2.441	1.626	0.225	1.304	-33.4%
Areys Pond	1.304	0.915	0.181	4.929	-29.8%
Namequoit River	2.737	1.732	0.523	12.232	-36.7%
Paw Wah Pond	1.860	0.728	0.082	2.665	-60.9%
Pochet Neck	8.422	4.123	1.767	-0.622	-51.0%
Little Pleasant Bay	8.134	5.878	24.086	35.222	-27.7%
Quanset Pond	1.781	1.079	0.170	4.787	-39.4%

(1) Composed of combined natural background, fertilizer, runoff, and septic system loadings.
(2) Target threshold watershed load is the load from the watershed needed to meet the embayment threshold concentration identified in Table ES-1.
(3) Projected future flux (present rates reduced approximately proportional to watershed load reductions).

Table ES-2b. Present Watershed Loads, Thresholds Loads, and the percent reductions necessary to achieve the threshold concentrations identified for the Pleasant Bay system.

Sub-embayments	Present Watershed Load [1] (kg/day)	Target Threshold Watershed Load [2] (kg/day)	Direct Atmospheric Deposition (kg/day)	Benthic Flux Net [3] (kg/day)	Percent watershed reductions needed to achieve threshold load levels
PLEASANT BAY SYSTEM					
Round Cove	4.225	2.960	0.170	6.739	-29.9%
Muddy Creek - upper	9.981	4.614	0.162	2.700	-53.8%
Muddy Creek - lower	8.477	2.137	0.205	-0.710	-74.8%
Pleasant Bay	29.282	21.845	37.005	96.170	-25.4%
Bassing Harbor - Ryder Cove	9.819	4.466	1.296	6.705	-54.5%
Bassing Harbor - Frost Fish Creek	2.904	0.704	0.096	-0.087	-75.8%
Bassing Harbor - Crows Pond	4.219	4.219	1.389	0.612	0.0%
Bassing Harbor	1.668	1.668	1.071	-4.460	0.0%
Chatham Harbor	17.099	17.099	14.153	-38.398	0.0%
Pleasant Bay System Total	**127.203**	**81.032**	**85.693**	**150.264**	**-36.3%**

(1) Composed of combined natural background, fertilizer, runoff, and septic system loadings.
(2) Target threshold watershed load is the load from the watershed needed to meet the embayment threshold concentration identified in Table ES-1.
(3) Projected future flux (present rates reduced approximately proportional to watershed load reductions).
(4) Sum of target threshold watershed load, atmospheric deposition load, and benthic flux load.

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APPENDIX P

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Mashpee, MA 02649

MEMORANDUM

Date: September 22, 2008

To: Brian Howes, Ph.D., School for Marine Science and Technology, University of Massachusetts, Dartmouth

From: Sean Kelley, P.E. and John Ramsey, P.E.

Subject: Pleasant Bay Water Quality Model Update and Scenarios

The Pleasant Bay model, updated recently to include the new north inlet (Kelley, 2008), was used to model N concentrations in the system to estimate the effect of the new breach on water quality. The hydrodynamic data to support the post breach conditions was collected in November 2008.

In addition to the update of the water quality model to include the north breach, two model scenarios were run to simulate water quality conditions under 2 different possible future hydrodynamic conditions. The scenarios are for 1) worst-case conditions where a single inlet has migrated to the maximum southerly position near Monomoy Island (similar to the pre 1987 breach condition of the system) and 2) a possible future configuration of the system with one north inlet, based on the historical behavior of Nauset Beach after past breaches.

The dispersion coefficients determined in the calibration of the 2006 Massachusetts Estuary Project (MEP) report (Howes, *et al*., 2006) were used for the updated post-breach model and scenarios simulations. The hydrodynamic input for each water quality case was modeled using the same tidal open boundary used for the MEP report in order to facilitate the comparison of each scenario with the modeled 2004 conditions. A map of water quality stations used for this comparison is presented in Figure 1. As with the MEP analysis, the bioactive component of TN (DIN+PON) was modeled for all the scenarios in this analysis. A plot showing the gradient in bio-active N concentrations throughout the Pleasant Bay System under 2004 (pre-breach) hydrodynamic conditions is shown in Figure 2.

A. Post North Breach, 2007 Conditions

The water quality model run of 2007 Pleasant Bay with the north breach and south inlet (post-breach conditions) uses the present N loading developed as part of the MEP report for the system. The N loading by embayment is presented in Table 1. A

Figure 1. Estuarine water quality monitoring station locations in the Pleasant Bay estuary system. Stations are monitored by the Pleasant Bay Alliance and Town of Chatham Water Quality Monitoring Programs.

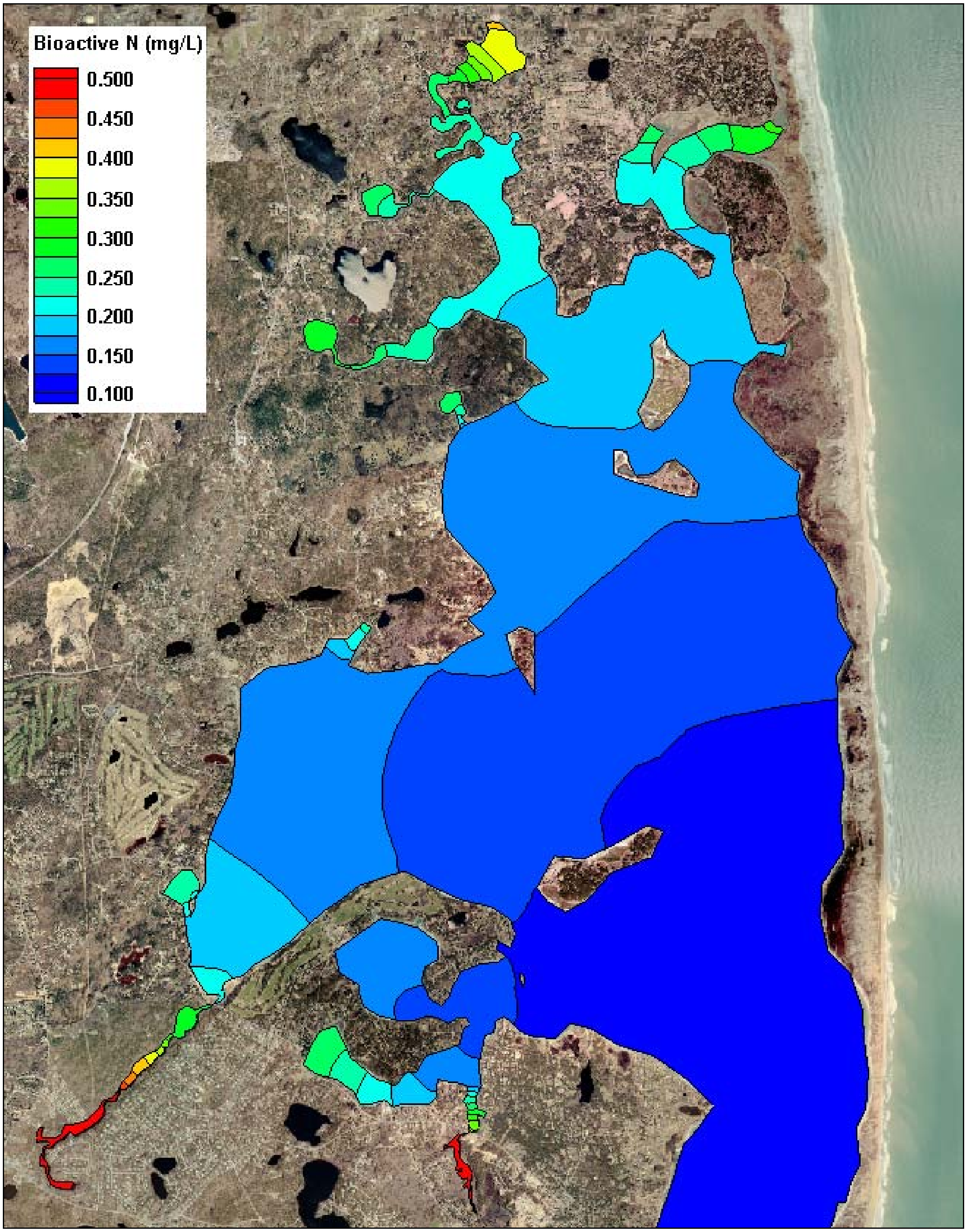

Figure 2. Color contour plot of model results representing present watershed loading and pre-breach hydrodynamic conditions. Contours indicate bioactive N concentrations, in mg/L.

Table 1. Sub-embayment and surface water loads used for total nitrogen modeling of the Pleasant Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent **present loading** conditions for the listed sub-embayments. Loads are from Howes, *et al*. (2006).			
sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)
Meetinghouse Pond	6.197	0.584	14.365
The River – upper	2.773	0.288	6.263
The River – lower	3.879	2.241	10.480
Lonnies Pond	2.441	0.225	1.591
Areys Pond	1.304	0.181	5.996
Namequoit River	2.737	0.523	14.570
Paw Wah Pond	1.860	0.082	3.630
Pochet Neck	8.422	1.767	-0.791
Little Pleasant Bay	7.496	24.023	37.226
Quanset Pond	1.781	0.170	5.988
Tar Kiln Stream	6.123	0.066	-
Round Cove	4.225	0.170	8.416
The Horseshoe	0.638	0.063	-
Muddy Creek - upper	9.981	0.162	4.560
Muddy Creek - lower	8.477	0.205	-1.226
Pleasant Bay	23.159	19.153	149.013
Pleasant Bay/Chatham Harbor Channel	-	17.786	-40.192
Bassing Harbor - Ryder Cove	9.819	1.296	9.356
Bassing Harbor - Frost Fish Creek	2.904	0.096	-0.154
Bassing Harbor - Crows Pond	4.219	1.389	0.612
Bassing Harbor	1.668	1.071	-4.976
Chatham Harbor	17.099	14.153	-40.208
TOTAL - Pleasant Bay System	**127.203**	**85.693**	**184.519**

complete discussion of the loads and how they are applied in the model is provided in the MEP report.

Tidally averaged bio-active N concentrations from the simulation period are presented in Figure 2 and Table 2, for the post-breach simulation. N concentrations decrease at all locations in the system compared to the 2004 pre-breach conditions. Changes at the monitoring stations range between a 23.4% decrease (relative to the background N concentration of the ocean) in lower Muddy Creek to a smaller 3.1% decrease at the Chatham Harbor monitoring station.

The difference between pre- and post-breach water quality conditions is shown in Figure 4. For this plot, pre-breach tidally averaged N concentrations were subtracted from the results of the post-breach simulation and the resulting difference in bioactive N, as mg/L. mapped. Again, both model runs used hydrodynamic model output based on the measured 2004 offshore tide used in the original MEP analysis. This map of change shows that the greatest change occurs in the embayments farthest from the inlet. Muddy Creek and Meetinghouse Pond have the darkest contours, which indicate the greatest decrease in N concentrations from pre-breach conditions.

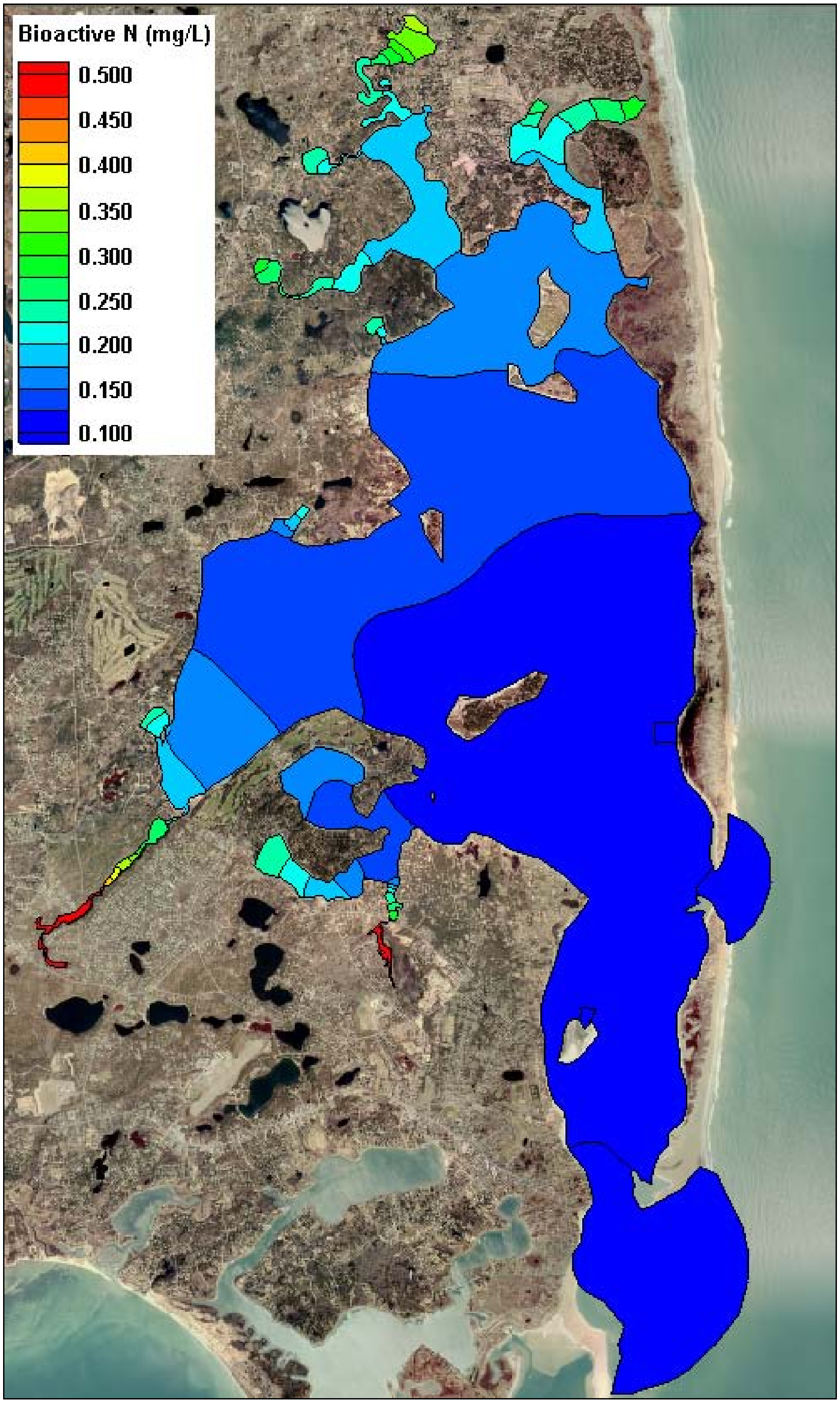

Figure 3. Color contour plot of bioactive N concentrations throughout the Pleasant Bay System for present watershed loading conditions with 2007 post-breach hydrodynamic conditions.

Table 2.	Comparison of model average bioactive N (DIN+PON) concentrations from present loading with 2004 pre- and 2007 post-breach hydrodynamic conditions, with percent change, for the Pleasant Bay system. Both model runs use the 2004 measure offshore Atlantic tide as the forcing boundary condition. The percent change is computed relative to N concentrations above the background offshore N concentration (0.094 mg/L). The threshold stations for eelgrass restoration are shown in bold print (0.16 mg/L at PBA-12 and the average of PBA-03 and CM-13) and for benthic infauna restoration are shown in italics (0.21 mg/L at WMO-10, WMO-8, WMO-6, WMO-5, PBA-11, WMO-12, and PBA-05).

Sub-Embayment	monitoring station	2004 (mg/L)	2007 (mg/L)	% change from background
Meetinghouse Pond	PBA-16	0.380	0.340	-14.1%
Meetinghouse Pond (Outer)	*WMO-10*	*0.261*	*0.243*	*-11.1%*
The River – upper	WMO-09	0.239	0.221	-12.3%
The River – mid	WMO-08	0.211	0.191	-17.1%
Lonnies Pond (Kescayo Ganset Pond)	*PBA-15*	*0.250*	*0.227*	*-14.8%*
Areys Pond	PBA-14	0.297	0.274	-11.1%
Namequoit River - upper	*WMO-6*	*0.239*	*0.220*	*-12.9%*
Namequoit River - lower	WMO-7	0.216	0.196	-16.1%
The River – lower	PBA-13	0.195	0.174	-20.4%
Pochet – upper	*WMO-05*	*0.269*	*0.253*	*-8.9%*
Pochet - lower	WMO-04	0.209	0.203	-5.3%
Pochet – mouth	WMO-03	0.183	0.170	-14.9%
Little Pleasant Bay - head	**PBA-12**	**0.178**	**0.158**	**-23.4%**
Little Pleasant Bay - main basin	PBA-21	0.162	0.144	-26.1%
Paw Wah Pond	*PBA-11*	*0.257*	*0.230*	*-16.8%*
Little Quanset Pond	*WMO-12*	*0.229*	*0.211*	*-13.1%*
Quanset Pond	WMO-01	0.191	0.173	-18.4%
Round Cove	*PBA-09*	*0.241*	*0.224*	*-11.5%*
Muddy Creek – upper	PBA-05a	0.674	0.626	-4.8%
Muddy Creek – lower	*PBA-05*	*0.286*	*0.251*	*-10.5%*
Pleasant Bay – head	PBA-08	0.149	0.133	-30.2%
Pleasant Bay - off Quanset Pond	WMO-02	0.160	0.142	-27.8%
Pleasant Bay- upper Strong Island	PBA-19	0.117	0.112	-23.5%
Pleasant Bay - mid west basin	PBA-07	0.168	0.149	-25.4%
Pleasant Bay - off Muddy Creek	PBA-06	0.192	0.173	-18.9%
Pleasant Bay - Strong Island channel	PBA-20	0.124	0.117	-24.8%
Ryders Cove – upper	**PBA-03**	**0.250**	**0.229**	**-13.0%**
Ryders Cove – lower	**CM-13**	**0.158**	**0.150**	**-11.3%**
Frost Fish – lower	CM-14	0.243	0.236	+2.3%
Crows Pond	PBA-04	0.162	0.151	-15.8%
Bassing Harbor	PBA-02	0.127	0.122	-16.3%
Pleasant Bay - lower	PBA-18	0.116	0.113	-14.8%
Chatham Harbor - upper	PBA-01	0.104	0.104	-3.1%

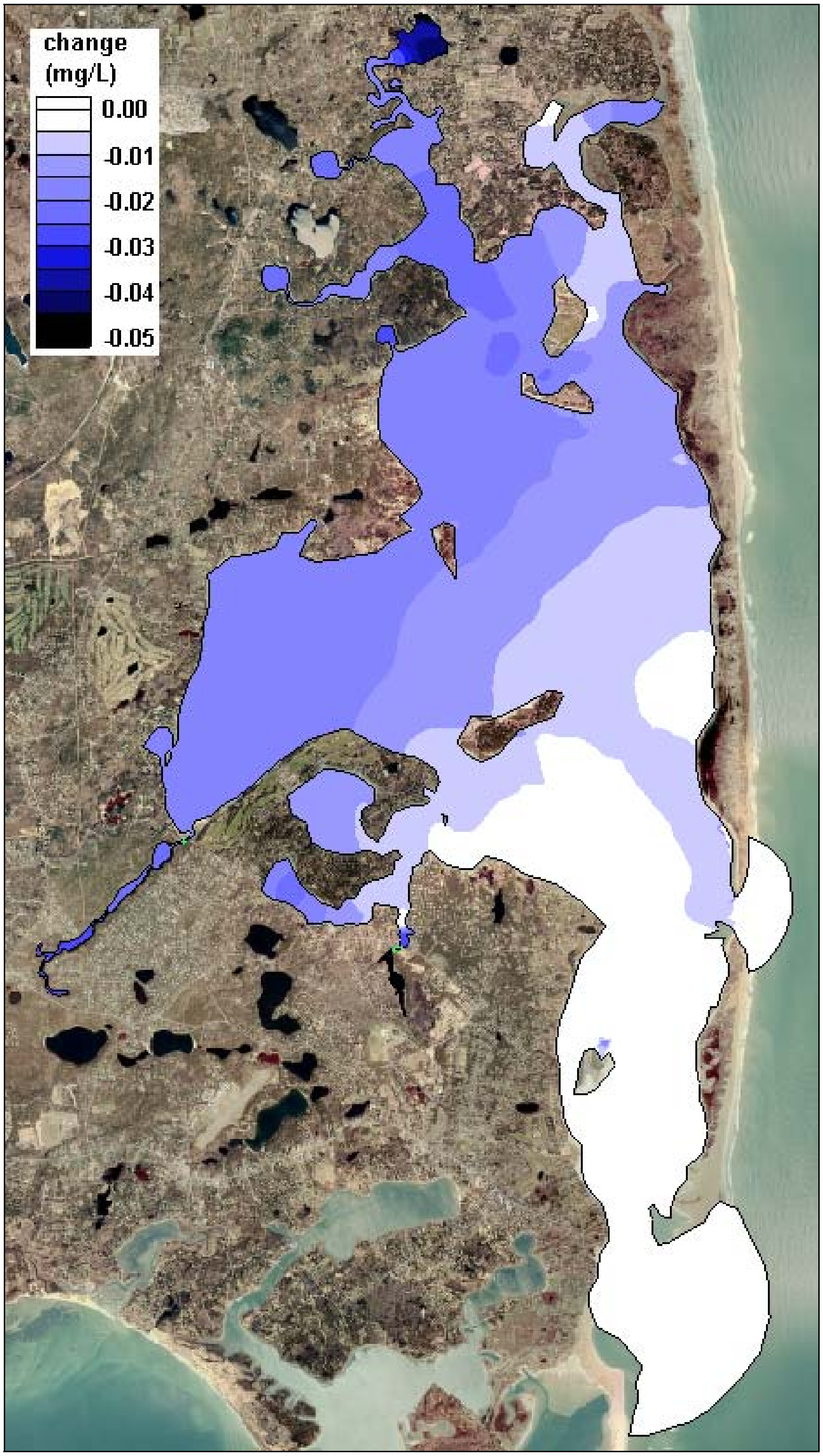

Figure 4. Color contours showing change in bioactive N concentration between post- (2007) and pre-breach (2004) hydrodynamic conditions for Pleasant Bay. Negative values indicate a decrease in post-breach concentrations compared to pre-breach condition. Both simulations were run using measured 2004 tides and present watershed loading.

The reductions at the primary critical N threshold stations are not enough to achieve the 0.16 mg/L level that is restorative to eelgrass. The primary threshold stations are at PBA-12 (at the head of Pleasant Bay), and the mid-point between PBA-3 and CM-13, in Ryder Cove. The reduction also is not enough to meet the requirements of the secondary benthic infauna threshold (0.21 mg/L) at any of the secondary threshold stations (indicated in Table 2). Therefore, though there is an improvement in N concentrations throughout the system, further reductions in the watershed load would be required in order to achieve conditions that are completely restorative to eelgrass and benthic infauna habitat.

B. Worst Case Inlet Scenario

The first model scenario is designed to simulate the likely worst case hydrodynamic conditions for the Pleasant Bay system. This scenario is based on the location of the southern inlet prior to the 1987 breach. Tidal flushing in Pleasant Bay is reduced in this scenario due to two main factors: first, a long inlet channel which has a greater drag on hydrodynamic flow; and second, a reduced tide range resulting from the greater influence of Nantucket Sound. The tide range at the entrance to Stage Harbor is approximately 60% of the range offshore Nauset Beach near Tern Island.

Since no tidal record exists for the inlet from the pre 1987 breach, it was necessary to develop a tidal boundary condition for the first scenario based on assumptions of the condition of the Pleasant Bay system in the 1950’s. This time represents the earliest period for which the extent of eel grass across the system has been estimated (MassDEP Eelgrass Mapping Program). The inlet then was also located at its historical maximum southern excursion. Therefore, we derived an estimate of the 1950 total N load and then using this load, the tide range at the inlet was adjusted until the simulated distribution of N concentrations across Pleasant Bay that were supportive of the eel grass distribution determined for the 1950’s.

The estimate of N loading for 1950 is an approximation, based on a reduced atmospheric deposition load, as well as a reduced upland nitrogen load. As a first estimate, 100% of the attenuated septic load was removed relative to existing conditions. This septic load removal was intended to account for groundwater travel times and to offset other loads that were unchanged from present conditions, including fertilizer and run-off. The watershed and atmospheric load to the bay estimated for 1950 was 45% lower than that for today. The benthic flux loading was also reduced (according to the method described in Howes, *et al*., 2006) to account for the effect of a reduced N load to the system.

Using the 1950 estimated load, the tide range at the inlet was adjusted until the N concentrations in the areas where eel grass existed in 1950 were equal to or less than 0.16 mg/L, which is the threshold bio-active N concentration determined for eel grass in Pleasant Bay. The adjusted tide that achieved this level was 90% of the range of the open Atlantic tide.

Finally, using the adjusted tide, a model run was made to determine N concentrations in Pleasant Bay using present loading with 100% septic removal. By removing all septic loads in this scenario, the effect of the combination of the best case N loading and worst-case hydrodynamic can be simulated. A tabulation of loads used in this simulation is provided in Table 3.

Model output for this scenario is presented in Table 4. At both primary sentinel stations, in upper Pleasant Bay and in Ryder Cove, the bio-active N concentration exceeds the threshold limit of 0.16 mg/L. The secondary benthic infauna threshold level of 0.21 mg/L is achieved at all secondary stations. Therefore, even with removal of all septic loads, the primary threshold would not be met.

Table 3.	Sub-embayment and surface water loads used for total nitrogen modeling of the Pleasant Bay system, with total watershed N loads, atmospheric N loads, and benthic flux. These loads represent "**no-septic**" conditions (present loading with 100% septic removal) for the listed sub-embayments.		
sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)
Meetinghouse Pond	1.058	0.584	7.857
The River – upper	0.701	0.288	3.740
The River – lower	1.008	2.241	7.581
Lonnies Pond	0.811	0.225	1.017
Areys Pond	0.526	0.181	3.862
Namequoit River	0.726	0.523	9.894
Paw Wah Pond	0.351	0.082	2.343
Pochet Neck	1.808	1.767	-0.531
Little Pleasant Bay	2.984	24.023	33.373
Quanset Pond	0.378	0.170	3.586
Tar Kiln Stream	4.326	0.066	-
Round Cove	1.063	0.170	4.224
The Horseshoe	0.164	0.063	-
Muddy Creek - upper	2.825	0.162	2.080
Muddy Creek - lower	2.137	0.205	-0.632
Pleasant Bay	10.082	19.153	120.498
Pleasant Bay/Chatham Harbor Channel	-	17.786	-36.009
Bassing Harbor - Ryder Cove	2.682	1.296	5.822
Bassing Harbor - Frost Fish Creek	0.704	0.096	-0.087
Bassing Harbor - Crows Pond	0.893	1.389	0.444
Bassing Harbor	0.268	1.071	-4.014
Chatham Harbor	2.904	14.153	-36.727
TOTAL - Pleasant Bay System	**38.400**	**85.693**	**128.319**

C. Single North Inlet Scenario

For the single north inlet scenario, a hydrodynamic model was developed based largely on the model for 2007 conditions, but also an estimate of how the north-south inlet complex will change through the coming decades. The estimate of the future condition of the inlet was in turn based present and historical data including the record of past breaches, present shoreline erosion/recession of Nauset Beach, and present inlet cross-sectional area. Graham Giese of the Provincetown Center for Coastal Studies provided input in the development of this inlet scenario. The shoreline used for this scenario is presented in Figure 5.

Table 4. Comparison of model average bioactive N (DIN+PON) concentrations from present loading with 2004 pre-breach and the no-septic loading scenario using 1986 hydrodynamic conditions, with percent change, for the Pleasant Bay system. Both model runs use the 2004 measure offshore Atlantic tide as the forcing boundary condition. The percent change is computed relative to N concentrations above the background offshore N concentration (0.094 mg/L). The threshold stations for eelgrass restoration are shown in bold print (0.16 mg/L at PBA-12 and the average of PBA-03 and CM-13) and for benthic infauna restoration are shown in italics (0.21 mg/L at WMO-10, WMO-8, WMO-6, WMO-5, PBA-11, WMO-12, and PBA-05).

Sub-Embayment	monitoring station	2004 (mg/L)	scenario one (mg/L)	% change from background
Meetinghouse Pond	PBA-16	0.380	0.270	-38.5%
Meetinghouse Pond (Outer)	*WMO-10*	*0.261*	*0.211*	-30.1%
The River – upper	WMO-09	0.239	0.200	-26.9%
The River – mid	WMO-08	0.211	0.186	-21.1%
Lonnies Pond (Kescayo Ganset Pond)	*PBA-15*	*0.250*	*0.207*	*-27.6%*
Areys Pond	PBA-14	0.297	0.245	-25.7%
Namequoit River - upper	*WMO-6*	*0.239*	*0.206*	*-22.5%*
Namequoit River - lower	WMO-7	0.216	0.191	-20.3%
The River – lower	PBA-13	0.195	0.178	-16.9%
Pochet – upper	*WMO-05*	*0.269*	*0.201*	*-38.9%*
Pochet - lower	WMO-04	0.209	0.182	-23.7%
Pochet – mouth	WMO-03	0.183	0.171	-13.1%
Little Pleasant Bay - head	**PBA-12**	**0.178**	**0.167**	**-12.7%**
Little Pleasant Bay - main basin	PBA-21	0.162	0.156	-7.9%
Paw Wah Pond	*PBA-11*	*0.257*	*0.209*	*-29.3%*
Little Quanset Pond	*WMO-12*	*0.229*	*0.182*	*-35.1%*
Quanset Pond	WMO-01	0.191	0.172	-19.6%
Round Cove	*PBA-09*	*0.241*	*0.196*	*-30.4%*
Muddy Creek - upper	PBA-05a	0.674	0.357	-54.6%
Muddy Creek - lower	*PBA-05*	*0.286*	*0.206*	*-41.9%*
Pleasant Bay – head	PBA-08	0.149	0.149	-1.4%
Pleasant Bay - off Quanset Pond	WMO-02	0.160	0.156	-6.1%
Pleasant Bay- upper Strong Island	PBA-19	0.117	0.123	+23.9%
Pleasant Bay - mid west basin	PBA-07	0.168	0.161	-9.8%
Pleasant Bay - off Muddy Creek	PBA-06	0.192	0.174	-18.8%
Pleasant Bay - Strong Island channel	PBA-20	0.124	0.128	+13.6%
Ryders Cove - upper	**PBA-03**	**0.250**	**0.187**	**-40.4%**
Ryders Cove - lower	**CM-13**	**0.158**	**0.145**	**-20.7%**
Frost Fish – lower	CM-14	0.243	0.181	-41.8%
Crows Pond	PBA-04	0.162	0.148	-20.2%
Bassing Harbor	PBA-02	0.127	0.129	+4.8%
Pleasant Bay – lower	PBA-18	0.116	0.121	+22.9%
Chatham Harbor - upper	PBA-01	0.104	0.110	+64.3%

Figure 5. Conceptualization of a single north inlet used for the development of the water quality model run of scenario two.

The 1850's breach that occurred in a location similar to the 2007 breach (Giese, 1988) was used as the model for the future behavior of the inlet. As the inlet continues to evolve, it is likely that the existing Nauset Beach remnant between the two inlets will move landward, and eventually weld to the mainland in a way similar to the progression of the south inlet after the breach in 1987. The north inlet will migrate south as Nauset Beach spit (which forms the north boundary of the north inlet) grows southward.

The landward migration of Nauset Beach into pleasant bay will also continue, as a result of continued sea level rise and shoreline retreat. In the next five decades the Nauset Beach shoreline is expected to move approximately 330 feet (100 meters) landward, based on past trends in shoreline change.

The inlet cross section used in the model of this scenario was based on the cross sectional area of the south inlet in 2004, prior to the north inlet breach. From the pre-breach bathymetry, the minimum inlet mid-tide cross-sectional area was determined to be approximately 15,200 ft^2. The cross section of the channel for the single north inlet scenario was made approximately 15% smaller to account for the reduced tide prism of the future scenario, since Chatham Harbor is not connected to the main basin of Pleasant Bay.

With the development of the model grid for the second scenario, hydrodynamics were run using the same 2004 time period used in the modeling of 2007 and in the first scenario. The water quality model was then run using the present N loading (Table 1) with the Chatham Harbor load removed. The bioactive N concentrations and the computed percent change from model 2004 conditions are presented in Table 5.

The resulting tidally averaged N concentrations are comparable to those computed in the simulation of 2007 post-breach conditions. The computed change from 2004 conditions is therefore also comparable. The second scenario results show a slight improvement over modeled 2007 conditions, with the greatest relative improvements seen in the main basin of Pleasant Bay . The single north inlet would offer further minor improvement in water quality compared to 2007 conditions, since the main basin of Pleasant Bay would have a more direct connection with the open Atlantic Ocean in this scenario. However, similar to 2007 post-breach conditions, the changes are not great enough to meet the threshold concentrations set for the restoration of eel grass and benthic infauna.

D. References

Giese, G.S. (1988). “Cyclical Behavior of the Tidal Inlet at Nauset Beach, Massachusetts: Application to Coastal Resource Management.” In: Lecture Notes on Coastal and Estuarine Studies, Volume 29, Symposium on Hydrodynamics and Sediment Dynamics of Tidal Inlets (D. Aubrey and L. Weishar, eds.), Springer-Verlag, NY, pp. 269-283.

Howes B., S. W. Kelley, J. S. Ramsey, R. Samimy, D. Schlezinger, E. Eichner (2006). Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Pleasant Bay, Chatham, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA. 227pp. Available online at http://www.oceanscience.net/estuaries/

Kelley, S.W., J.S. Ramsey (2008). Hydrodynamic Model of Chatham Harbor/Pleasant Bay including 2007 North Breach. Technical Memo. Applied Coastal Research and Engineering, Mashpee, MA. 24 pp.

Table 5. Comparison of model average bioactive N (DIN+PON) concentrations from present loading with 2004 pre- and projected future single north inlet hydrodynamic conditions, with percent change, for the Pleasant Bay system. Both model runs use the 2004 measure offshore Atlantic tide as the forcing boundary condition. The percent change is computed relative to N concentrations above the background offshore N concentration (0.094 mg/L). The threshold stations for eelgrass restoration are shown in bold print (0.16 mg/L at PBA-12 and the average of PBA-03 and CM-13) and for benthic infauna restoration are shown in italics (0.21 mg/L at WMO-10, WMO-8, WMO-6, WMO-5, PBA-11, WMO-12, and PBA-05).

Sub-Embayment	monitoring station	2004 (mg/L)	scenario two (mg/L)	% change from background
Meetinghouse Pond	PBA-16	0.380	0.355	-8.7%
Meetinghouse Pond (Outer)	*WMO-10*	*0.261*	*0.247*	*-8.4%*
The River - upper	WMO-09	0.239	0.225	-9.7%
The River – mid	WMO-08	0.211	0.195	-13.4%
Lonnies Pond (Kescayo Ganset Pond)	*PBA-15*	*0.250*	*0.233*	*-10.7%*
Areys Pond	PBA-14	0.297	0.280	-8.3%
Namequoit River - upper	*WMO-6*	*0.239*	0.224	-10.6%
Namequoit River - lower	WMO-7	0.216	0.200	-13.0%
The River - lower	PBA-13	0.195	0.178	-16.3%
Pochet – upper	*WMO-05*	*0.269*	*0.264*	*-2.8%*
Pochet - lower	WMO-04	0.209	0.209	0.0%
Pochet – mouth	WMO-03	0.183	0.175	-9.3%
Little Pleasant Bay - head	**PBA-12**	**0.178**	**0.162**	**-18.9%**
Little Pleasant Bay - main basin	PBA-21	0.162	0.147	-22.1%
Paw Wah Pond	*PBA-11*	*0.257*	*0.238*	*-11.6%*
Little Quanset Pond	*WMO-12*	*0.229*	*0.210*	*-14.2%*
Quanset Pond	WMO-01	0.191	0.172	-20.1%
Round Cove	*PBA-09*	*0.241*	*0.221*	*-13.5%*
Muddy Creek - upper	PBA-05a	0.674	0.644	-5.2%
Muddy Creek - lower	*PBA-05*	*0.286*	*0.264*	*-11.6%*
Pleasant Bay - head	PBA-08	0.149	0.133	-30.2%
Pleasant Bay - off Quanset Pond	WMO-02	0.160	0.140	-30.2%
Pleasant Bay- upper Strong Island	PBA-19	0.117	0.111	-29.5%
Pleasant Bay - mid west basin	PBA-07	0.168	0.147	-28.2%
Pleasant Bay - off Muddy Creek	PBA-06	0.192	0.171	-21.3%
Pleasant Bay - Strong Island channel	PBA-20	0.124	0.113	-37.1%
Ryders Cove - upper	**PBA-03**	**0.250**	**0.231**	**-12.7%**
Ryders Cove - lower	**CM-13**	**0.158**	**0.148**	**-16.8%**
Frost Fish - lower	CM-14	0.243	0.240	-2.5%
Crows Pond	PBA-04	0.162	0.150	-18.6%
Bassing Harbor	PBA-02	0.127	0.117	-29.6%

APPENDIX Q

Nitrogen Removal Potential from Shellfish Aquaculture

Mashpee River, Popponesset Bay Watershed
March 30 2005

By Rick York
Town of Mashpee Shellfish Constable

N REMOVAL PROCESSES

- Filter feeding shellfish can mitigate eutrophication (Officer et al., 1982). Shellfish remove nitrogen by filtering algae (phytoplankton and suspended benthic microalgae), organic particles and dissolved organic nitrogen from the water for food. Algae remove dissolved inorganic nitrogen from the water for growth. Nitrogen is removed when people harvest the shellfish.
- Shellfish fecal material in sediments under shellfish aquaculture sites has been shown to increase denitrification by bacteria (Kasper et al., 1985). This has the potential to remove even more nitrogen than the harvest of the shellfish.
- Oysters are the best shellfish for the Mashpee River because they can grow at very low salinities where the nitrogen concentrations are the highest (most of the nitrogen enters the estuary in fresh water), and nitrogen removal will be most effective for reducing impacts in the rest of the estuary. There are fewer oyster predators and diseases in low salinity waters.
- Oyster meat is estimated to be 1.68% N on average (Rice, 2001). Most oysters grow from seed to harvest size in 1.5 to 3 years in Mashpee. Annual seeding for a harvest of 2 million oysters per year could remove more than 500 kg N per year.

PROJECT STATUS

- June 2004 - start of project: 200 cultch bags with oyster spat (newly set seed) placed in trays in Mashpee River (1 km up from mouth of river, low tide salinities <10 PPT).
- Fall 2004 - >150,000 oyster seed grew to sizes between 1" and just under 3" (3" is harvest size).
- Water quality background and ongoing monitoring - continuous monitoring (YSI sonde) in river, and sampling for lab analysis. Parameters include temp., salinity, dissolved oxygen, pH, chlorophyll, nitrogen, suspended solids, algal density/identification.
- Mass. Division of Marine Fisheries and Barnstable County supports cost of oyster seed. AmeriCorps Cape Cod and volunteers help with aquaculture and monitoring. The Town of Mashpee Shellfish Dept. covers other costs (trays, monitoring, project management, etc.).
- 2005 Plans - Stock 200 new cultch bags with oyster seed. Continue water quality monitoring. Document water quality improvement/nitrogen removal by sampling upstream and downstream sides of the oyster bed during tidal flow.
- Obtain funding for continuous water quality monitoring units (YSI sondes) upstream and downstream of oyster bed. Measure nitrogen content of the oysters. Measure denitrification in sediments under oyster trays and control sites elsewhere in river.

POTENTIAL IMPACT ON TMDL REDUCTION EFFORTS

- The goal is removal of 500 kg N per year. This is 10% of the 5000 kg N per year target N reduction for the Mashpee River in the scenario used in the Estuaries Project report on Popponesset Bay (Howes et al., 2004).
- This is a biological system with risks including disease, predators and severe weather. Diversification to include other species of shellfish could reduce some risks.

- Because this is still in the research/pilot phase, it is not a good candidate to include in modeling of N reductions. Best viewed as a potential contributor to Bay restoration.

LITERATURE

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APPENDIX R

Town of Mashpee
Stormwater Management Bylaw
§174-27.2

History: Added 3-5-1999, ATM, Article 45, approved by Attorney General on 7-29-1999.

A. For any new residential or non-residential development requiring either subdivision approval, a special permit, plan review under the provisions of Subsection 174-24.B., or a building permit for a building over one thousand (1000) square feet in area a system of stormwater management and artificial recharge of precipitation shall be required which is designed to achieve the following purposes: prevent untreated discharges to wetlands and surface waters, preserve hydrologic conditions that closely resemble pre-development conditions, reduce or prevent flooding by managing the peak discharges and volumes of runoff, minimize erosion and sedimentation, not result in significant degradation of groundwater, reduce suspended solids, nitrogen, volatile organics and other pollutants to improve water quality and provide increased protection of sensitive natural resources.

B. These standards may be met using the following or similar best management practices:

1. For new single or two-family residences, recharge shall be attained through site design that incorporates natural drainage patterns and vegetation in order to maintain pre-development stormwater patterns and water quality to the greatest extent possible. Stormwater runoff from rooftops, driveways and other impervious surfaces shall be routed through vegetated water quality swales, as sheet flow over lawn areas or to constructed stormwater wetlands, sand filters, organic filters and/or similar systems capable of removing nitrogen from stormwater.

2. For new subdivision roadways or for lots occupied or proposed to be occupied by uses other than single or two-family homes, a stormwater management plan which 1) utilizes site planning and building techniques, such as minimizing impervious surfaces and disturbance of existing natural areas, pervious reserve or overflow parking areas, multi-level buildings, parking structures, "green roofs" and storage and re-use of roof runoff, to minimize runoff volumes and the level of treatment required to reduce contaminants, 2) minimizes erosion and runoff from disturbed areas during construction and 3) provides for artificial recharge or precipitation to groundwater through site design that incorporates natural drainage patterns and vegetation and through the use of constructed (stormwater) wetlands, bioretention facilities, vegetated filter strips, rain gardens, wet (retention) ponds, water quality swales, organic filters or similar-site-appropriate current best management practices capable of removing significant amounts of nitrogen and other contaminants from stormwater. Said stormwater treatment facilities shall be designed and sized to retain up to the first inch of rainfall from their catchment area within the area designed for nitrogen treatment, before any overflow to subsurface leaching facilities and otherwise meet the Stormwater Management Standards and technical guidance contained in the Massachusetts

Department of Environmental Protection's *Stormwater Management Handbook*, Volumes 1 and 2, dated March 1997, for the type of use proposed and the soil types present on the site. Such runoff shall not be discharged directly to rivers, streams, other surface water bodies, wetlands or vernal pools. Except for overflow from stormwater treatment facilities as described above and when there are no other feasible alternatives, dry wells shall be prohibited. Except when used for roof runoff from non-galvanized roofs and for runoff from minor residential streets, all such wetlands, ponds, swales or other infiltration facilities shall be preceded by oil, grease and sediment traps or forebays or other best management practices to facilitate control of hazardous materials spills and removal of contamination and to avoid sedimentation of treatment and leaching facilities. All such artificial recharge systems shall be maintained in full working order by the owner(s) under the provisions of an operations and maintenance plan approved by the permitting authority to assure that systems function as designed. Infiltration systems shall be located so that no part of any leaching system is located less than one hundred (100) feet from drinking water wells. Any infiltration basins or trenches shall be constructed with a three (3) foot minimum separation between the bottom of the leaching system and maximum groundwater elevation.

C. The building inspector shall require the submission of sufficient plans and specifications to demonstrate the location and nature of proposed stormwater facilities for development under subsection B.(1) and shall require their implementation. For development under subsection B.(2), the permitting authority shall require the submission of sufficient plans and specifications to demonstrate the location, nature, operation and effectiveness of the proposed stormwater management facilities and practices and shall require their implementation and maintenance, including provisions for deed restrictions and other implementing provisions, as a condition of approval of the proposed development. No permit may be approved for a development unless the permitting authority determines in writing that the proposed system of stormwater management and artificial recharge will achieve the purposes described in subsection A.

APPENDIX S

Town of Mashpee
Board of Health Regulation

REGULATION TO PROTECT WATER QUALITY

PART IX: ON-SITE SEWAGE DISPOSAL REGULATIONS
SECTION 14.00 DESIGN FLOWS IN EXCESS OF 600 GALLONS PER DAY

1.0) PURPOSE - Water quality in certain areas of the Town of Mashpee is degraded. Excessive nitrogen loading in our watersheds has been identified as a major cause of this degradation. The primary source of excess nitrogen is wastewater from the on-site septic systems. This regulation is promulgated in an effort to decrease the amount of nitrogen contribution from septic systems.

2.0) AUTHORITY - This regulation is adopted by the Board of Health of the Town of Mashpee, Massachusetts, acting under the authority of Chapter 111, Section 31 and Chapter 21A, Section 13 of the Massachusetts General Laws and under Title 1 and Title 5 of the State Environmental Code (310 CMR 11.00 and 15.000).

3.0) DEFINITIONS - On site sewage disposal system or systems is a privy, cesspool, septic tank, holding tank, grease trap, sewerage treatment device or other structure, together with any associated sewer and/or leaching facilities, that is used to treat and dispose of sewage from any building or structure. The components of these systems typically consist primarily of subsurface structures.

4.0) APPLICABILITY - This regulation shall apply to all on-site sewage disposal systems located in the Town of Mashpee with a design flow in excess of 600 gallons per day.

5.0) NEW SYSTEMS - All new systems shall be designed to achieve no greater than 10 milligrams per liter (MG/L) total nitrogen concentration in the effluent. Systems meeting the 10 MG/L total nitrogen standard shall be tested and reported on a quarterly basis by means of a groundwater monitoring well located downgradient of the leaching facility 10" from the lot line.

5.0) EXISTING SEPTIC SYSTEMS - At the time of transfer of title of an existing facility served by a septic system, or in the event of the failure of or emergency repairs to any septic system, the septic system shall be upgraded to achieve no greater than 10 milligrams per liter (MG/L) total nitrogen concentration in the effluent. Systems meeting the 10 MG/L total nitrogen standard shall be tested and reported on a quarterly basis by means of a groundwater monitoring well located downgradient of the leaching facility 10' from the lot line.

6.0) VARIANCE
The Town of Mashpee, Board of Health in any particular case may vary the application of any provision of this regulation, when, it its opinion:

1) Effluent from proposed systems will not be discharged within the groundwater recharge area of the Waquoit or Popponesset Estuaries;
2) Such action is in the public interest and not inconsistent with the intent and purpose of the State Environmental Code and this regulation.
3) Strict enforcement would cause undue hardship and manifest injustice.

4) The same degree of environmental protection required under Title 5 (310 CMR 15.000) and this regulation can be achieved without strict application of the particular provisions. The burden of proof shall rest with the applicant as to all elements required for the approval of any variance. Any request for a variance must be in writing to the Board of Health and shall be acted on in accordance with procedures for the granting of a variance under Town of Mashpee, Board of Health regulations.

7.0) ENFORCEMENT
The Town of Mashpee, Board of Health, as permitted under the provision of Chapter 111, Section 31 and under Title 1 (310 CMR 11.00), may issue administrative enforcement orders, violation notices, requests for compliance and other documents and correspondence to enforce the provisions of this regulation. The Board may pursue criminal or non-criminal prosecution or civil litigation or both in the courts of the Commonwealth of Massachusetts to enforce the provisions of this regulation.

8.0) PENALTIES
Any penalty for failure to comply with any provision of this regulation shall be governed by Massachusetts General Laws, Chapter 111, Section 31. Each day of violation shall constitute a separate offense. Further, the Town of Mashpee, Board of Health, after notice to and after a public hearing thereon, may suspend, revoke or modify any license issued by the Board for due cause.

9.0) SEVERABILITY
Each part of this regulation shall be construed as separate, if any section, paragraph, sentence, clause, phrase or word of this regulation shall be declared invalid for any reason; the remainder of this regulation shall remain in full force and effect.

10.0) EFFECTIVENESS
Following a two-week public comment period this regulation was adopted by the Board of Health July 1, l999.

APPENDIX T

Town of Barnstable Board of Health Regulation
Protection of Saltwater Estuaries

Town of Barnstable
Board of Health
200 Main Street, Hyannis MA 02601

Office: 508-862-4644
FAX: 508-790-6304

Wayne Miller, M.D.
Paul Canniff, DMD
Junichi Sawayanagi

May 5, 2008

To: Barnstable Patriot

From: Thomas McKean, Division Manager
Barnstable Public Health Division

Re: Public Hearing, May 27th at 4:00 PM Regarding a Proposed Regulation entitled: Interim Regulation for the Protection of Saltwater Estuaries

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Legal Notice

The Board of Health of the Town of Barnstable Massachusetts in accordance with and under the authority granted by Section 31 of Chapter 111 of the General Laws of the Commonwealth of Massachusetts, for the purpose of alleviating the adverse impact to the saltwater estuaries from septic system wastewater discharges, hereby announces that there will be a public hearing to review and discuss a proposed new Section 360- 45 **Interim Regulation for the Protection of Saltwater Estuaries.**

The following restrictions are proposed within the draft Regulation:

B. RESTRICTIONS
No permit for the construction of an individual sewage disposal system shall be granted within the watersheds for the estuaries that have been identified as requiring a reduction in the current TMDL of nitrate-nitrogen as identified by the map titled "Massachusetts Estuary Project, Zones of Contribution to Saltwater Estuaries, Town of Barnstable, March 10, 2008" unless the following standards are met...

1. The maximum allowable discharge of sanitary sewage, based on the sewage design flow criteria listed in 310 CMR 15.203, Title 5, of the State Environmental Code, shall not exceed 440 gallons per forty thousand square feet of lot area with the following exceptions:

   (a) For approved building lots on which no dwelling currently exists and that are less than twenty thousand square feet in area the maximum allowable sewage discharge shall be 220 gallons.

(b) For parcels with existing dwellings the maximum allowable flow shall be either 440 gallons per forty thousand square feet except as described in 1(a) above or whatever is currently permitted, whichever is greater.

2. Nothing in this regulation shall prohibit the approval by the Board of Health of any application involving the maintenance, repair or alteration of an existing individual sewage disposal system, providing that said application does not involve a change of use or increase in design flow as defined by existing Board of Health regulations. Where a change of use or increase in design flow is involved, the applicant must demonstrate compliance with this regulation.

The public hearing will be held on **Tuesday May 27, 2008 at 4:00 p.m**. at the Town Hall, second floor Hearing Room, 367 Main Street, Hyannis, MA. The hearing will be held to provide citizens the opportunity to be heard.

Copies of the Regulation may be obtained and a copy of the proposed map may be viewed at the Public Health Division Office, 200 Main Street Hyannis.

A. Purpose.

(1) The purpose of this section is to create a Resource Protection Overlay District overlaying residential zoning districts, and, in part, the Groundwater Protection Overlay District. The boundaries of the Resource Protection Overlay District shall include the recharge areas to the Centerville River, Popponesset and Shoestring Bays, and the Three Bays area of Cotuit and Osterville, so-called, together with areas dependent upon private well water supplies, and shall be as shown on the Barnstable Zoning Map as described in Subsection C below. When regulations are in conflict, the more restrictive regulation shall apply.

(2) The Resource Protection Overlay District implements the Barnstable Local Comprehensive Plan, adopted by the Barnstable Town Council, October 30, 1997, and approved by the Cape Cod Commission, February 12, 1998. The purposes of the Resource Protection Overlay District include:

a) To reduce nitrogen contamination by reducing impacts from septic systems, fertilizers, and runoff from impervious surfaces, which contamination adversely affects groundwater, ponds and freshwater bodies, and south coastal marine embayments.
b) To reduce nitrogen loading to groundwater, surface water and coastal embayments to prevent deterioration of water quality, destruction of bottom habitat, loss of fin fish and shellfish habitat, closure of swimming areas, and other adverse environmental and economic impacts.
c) To increase protection of groundwater quality in areas where no public wastewater treatment and no public water supply is provided; to ensure protection of private drinking water wells; to protect private drinking water wells from adverse impacts in areas of varying soil conditions that are vulnerable to contamination of groundwater due to environmental conditions such as impervious soils, high groundwater levels or steep slopes; and to protect private wells from impacts from adjacent road drainage systems.
d) To reduce development potential. The Barnstable Local Comprehensive Plan identifies the potential for 36% more residential growth and a shortfall in public facilities to service that additional residential development. Potential shortfalls in public services include inadequate

roads, lack of capacity in public wastewater treatment facilities, lack of options for public water supply development, and lack of capacity of schools and recreational facilities.

B. Districts established. In order to implement the purpose of this section, the Resource Protection Overlay District is hereby established, and shall be superimposed over existing residential zoning districts established by this chapter, and as they may be amended from time to time.

C. Overlay Districts Map. The boundaries of the Resource Protection Overlay District established by this section are shown on the Official Zoning Map, § 240-6A, Identification of Zoning Map, as amended with a file date of October 26, 2000, and a title of "Resource Protection Overlay District."

D. Resource Protection Overlay District regulations. Within the Resource Protection Overlay District, the minimum lot area requirement of the bulk regulations in all residential zoning districts shall be 87,120 square feet.

ARTICLE XV
[Adopted 6-30-2008]
§ 360-45. Interim regulations.

A. Purpose.

(1) The findings of a state wide estuary investigation indicate that a substantial portion of the Town's salt water estuaries are in jeopardy from the long-term build-up of nitrate-nitrogen, primarily from the subsurface discharge of sewage effluent. These findings have caused the Massachusetts Department of Environmental Protection to establish total maximum daily loads (TMDL) for nitrogen for the watershed areas of these estuaries. "Watershed" is defined as the area of land from which water flows downhill into a particular body of water. In these nitrogen-impaired estuaries the TMDL will require an actual reduction in the amount of nitrate-nitrogen discharged into these embayments. Since most of the nitrate-nitrogen in these watersheds is from subsurface discharge of sewerage effluent into the groundwater that flows to these embayments and since it is likely that a plan for corrective action will take years to formulate and implement, the Board is adopting the following interim regulations to mitigate the adverse impact to these estuaries from such discharges.

(2) The Town has long recognized the need to protect its water resources and has imposed discharge limits on subsurface disposal of sewage in other nitrogen-sensitive areas. The restrictions proposed herein are similar to those imposed by Town ordinance and/or Board of Health regulation in other nitrogen-sensitive areas in the Town. These regulations are temporary and will be in effect only until the Town adopts and implements a comprehensive plan to address the nitrogen reduction required in these estuary systems by the proposed TMDL.

(3) To date, final reports have been produced for Popponesset Bay, Three Bays and the Centerville River watersheds. All three of these estuary systems will require a reduction in total nitrogen discharge in order to meet the state mandated TMDL. Further reports are expected on Lewis Bay and Barnstable Harbor. If these studies indicate a need for nitrogen reduction in those watersheds, the following rules will be applied to those watersheds also.

B. Restrictions. No permit for the construction of an individual sewage disposal system on a residential building lot shall be granted within the watersheds for the estuaries that have been identified as requiring a reduction in the current TMDL of nitrate-nitrogen as identified by the map entitled "Massachusetts Estuary Project, Zones of Contribution to Saltwater Estuaries, Town of Barnstable, March 10, 2008" unless the following standards are met:

(1) The maximum allowable discharge of sanitary sewage, based on the sewage design flow criteria listed in 310 CMR 15.203, Title 5, of the State Environmental Code, shall not exceed 440 gallons per 40,000 square feet of lot area with the following exceptions:

    (a) For approved building lots on which no building currently exists and that are less than 30,000 square feet in area, the maximum allowable sewage discharge shall be 330 gallons.

    (b) For parcels with existing buildings, the maximum allowable flow shall be either 440 gallons per 40,000 square feet, except as described in Subsection B(1)(a) above or whatever is currently permitted, whichever is greater.

(2) Nothing in this regulation shall prohibit the approval by the Board of Health of any application involving the maintenance, repair or alteration of an existing individual sewage disposal system, providing that said application does not involve an increase in design flow as defined by existing Board of Health regulations. Where an increase in design flow is involved, the applicant must demonstrate compliance with this regulation.

C. Variance. Variance from this regulation may be granted by the Board of Health only if the applicant can demonstrate that:

(1) Connection to Town sewer is not available; and
(2) That enforcement thereof would do manifest injustice; and
(3) The alternative proposal will provide the same degree of environmental protection as a design in full conformance with this regulation. This standard shall be met by a site/septic design which results in equilibrium concentrations of nitrate/nitrogen at the down gradient property line not exceeding 5ppm utilizing the Cape Cod Commission formulas found in their Technical Bulletin 91-001 (final). In undertaking this calculation the applicant may utilize offsite lands located elsewhere in the Estuaries Contribution Area as defined by the map entitled "Massachusetts Estuary Project, Zones of Contribution to Saltwater Estuaries, Town of Barnstable, March 10, 2008," provided that:
    (a) The existing nitrogen loading for the off-site property is included in the calculations; and
    (b) A deed restriction limiting the off-site property to the current nitrogen loading as stated in the calculations and running to the Barnstable Board of Health or other entity suitable to that Board is recorded at the Barnstable Registry of Deeds in the titles to both the subject property and the off-site property. The restriction shall be in a form suitable to the Barnstable Town Attorney. Proof of recording shall be provided to the Board of Health, the Town Assessing Department and the Town Building Department prior to the issuance of a DWIP for the subject property.

APPENDIX U

Barnstable's "Resource Protection Overlay District" Ordinance

BARNSTABLE TOWN COUNCIL

SECTION 1
THAT CODE OF THE TOWN OF BARNSTABLE, MASSACHUSETTS / PART 1: GENERAL ORDINANCES / Chapter 240, ZONING / Article III, District Regulations / § 240-36. RPOD Resource Protection Overlay District, is hereby amended as follows:
240-36 RPOD Resource Protection Overlay District

A. Purpose
(1) The purpose of this section is to create a Resource Protection Overlay District overlaying residential zoning districts, and, in part, the Groundwater Protection Overlay District. The boundaries of the Resource Protection Overlay District shall include the recharge areas to the Centerville River, Popponesset and Shoestring Bays, and the Three Bays area of Cotuit and Osterville, so-called, the re-charge areas to Barnstable Harbor and associated creeks and embayments, together with areas dependent upon private well water supplies. The Resource Protection Overlay District , and shall be as shown on the Barnstable Zoning Map as described in Subsection C below. When regulations are in conflict, the more restrictive regulation shall apply.
(2) The Resource Protection Overlay District implements the Barnstable Local Comprehensive Plan, adopted by the Barnstable Town Council, October 30, 1997, and approved by the Cape Cod Commission, February 12, 1998. The purposes of the Resource Protection Overlay District include:
(a) To reduce nitrogen contamination by reducing impacts from septic systems, fertilizers, and run-off from impervious surfaces, which contamination adversely §affects groundwater, ponds and freshwater bodies, south coastal marine embayments, and north coastal creeks and estuaries.
(b) To reduce nitrogen loading to groundwater, surface water and coastal embayments to prevent deterioration of water quality, destruction of bottom habitat, loss of fin fish and shellfish habitat, closure of swimming areas, closure of shellfish harvesting areas, and other adverse environmental and economic impacts.
(c) To increase protection of groundwater quality in areas where no public wastewater treatment and no public water supply is provided, to ensure protection of private drinking water wells. To protect private drinking water wells from adverse impacts in areas of varying soil conditions that are vulnerable to contamination of groundwater due to environmental conditions such as impervious soils, high groundwater levels or steep slopes, and to protect private wells from impacts from adjacent road drainage systems.
(d) To protect the sites and settings of historic properties and landscapes.
(e) To reduce development potential. The Barnstable Local Comprehensive Plan identifies the potential for 36% more residential growth and a shortfall in public facilities to service that additional residential development. Potential shortfalls in public services include inadequate roads, lack of capacity in public wastewater treatment facilities, lack of options for public water supply development, and lack of capacity of schools and recreational facilities.
B. Districts established. In order to implement the purpose of this section, the Resource Protection Overlay District is hereby established, and shall be superimposed over existing residential zoning districts established by this chapter, and as they may be amended from time to time.
C. Overlay Districts Map. The boundaries of the Resource Protection Overlay District established by this section are shown on the Official Zoning Map, § 240-6A, Identification of Zoning Map, as amended with a file date of October 26, 2000 April 15, 2005, and a title of "Resource Protection Overlay District.
D. Resource Protection Overlay District regulations. Within the Resource Protection Overlay District, the minimum lot area requirement of the bulk regulations in all residential zoning districts shall be 87,120 square feet.
SECTION 2

THAT CODE OF THE TOWN OF BARNSTABLE, MASSACHUSETTS / PART 1: GENERAL ORDINANCES / Chapter 240, ZONING / Article III, District Regulations / § 240-13. RC, RD, RF-1 and RG Districts, is hereby amended as follows:

By amending Section § 240-13 RC, RD, RF-1 and RG Residential Districts, sub-section E Bulk Regulations, by adding a double asterisk ** after the minimum lot area of the RG Zoning District of 65,000 (sq. ft.), to read as follows: 65,000**.

SECTION 3

THAT CODE OF THE TOWN OF BARNSTABLE, MASSACHUSETTS / PART 1: GENERAL ORDINANCES / Chapter 240, ZONING / Article II, General Provisions District Regulations / § 240-6. Zoning Map, is hereby amended as follows:

By amending the official Zoning Map established in § 240-6 Zoning Map, sub-section A, by adopting a revised map with a draft file date of April 15, 2005, which is on file with the Town Clerk. This revision shows the extension of the Resource Protection Overlay District RPOD to the residentially zoned districts of Barnstable Village, north of Rt. 6, the Mid-Cape Highway.

Sponsor:

DATE ACTION TAKEN

AGENDA ITEM SUMMARY

05-

TO: Town Council, Gary Brown President

FROM: Ann Canedy, Town Councilor

DATE: October 24, 2004

SUBJECT: Extension of the Resource Protection Overlay District to Barnstable Village, north of the Mid-Cape Highway

The town's Local Comprehensive Plan documented the need to increase lot sizes in the town in order to reduce the impact of development upon groundwater, drinking water supplies and freshwater and coastal embayments, and to reduce the impact of development upon the town's infrastructure. That plan recommended this increase be applied to Barnstable Village, as well as other areas of town.

In Barnstable Village there is added reason for this lot size, documented in the 1997 plan, and in the proposed draft village plan revisions. Most of the developable land in Barnstable Village is located on "estate lots", large lots that are developed, many of them with historic houses, and potentially sub-dividable. Views of historic houses and historic sites along Rt. 6A and other roadways will be affected by land subdivision and development in front of existing buildings, thus changing views along this most historic, regional roadway.

In October 2000, the Town Council voted to increase the minimum lot size in five of the town's villages, but despite a considerable amount of developable land in Barnstable Village, the Resource Protection Overlay District was not extended to this area, increasing development pressures on this historic village.

It should be noted that the Resource Protection Overlay District includes a provision in the Nonconforming Use section of the Ordinance to only apply the two-acre lot size increase to undivided land – there is no requirement to join adjacent, under-sized lots in the same ownership which are grandfathered from the two–acre requirement.

EXCERPT from the Preliminary Draft revised LCP for Barnstable Village

With the extension of two acre zoning to five out seven of the town's villages, development pressures have increased in this village, which still has substantial developable acreage. Undeveloped lands in this village include large tracts of land in old estates, along Route 6A, and the bay shore. Many historic houses are located on large lots in excess of two acres and therefore sub dividable. Some o the old wood lots along the Mid-Cape Highway remain to be developed. Elsewhere there are developable lots in subdivisions.

Developable acreage:
Developable acres on developed lots,
2 acres and greater: ……… 482 acres
Vacant lands ………………………………………345 acres
Total developable acreage: …………………827 acres
(Analysis of Assessors data, J. Etsten, Planning Division 2004)

In order to protect both natural resources and historic, scenic landscapes, residents expressed a strong desire to extend the increased lot size of two acres, to portions of Barnstable Village. Of immediate concern are the larger lots found along Rt. 6A, north to the harbor. This is the area of the greatest concentration of historic buildings, and the area of impervious soils where run-off can affect water quality in Barnstable Harbor, especially the adjacent flats and shellfish beds. A lot size increase should be promptly implemented before land division and development precludes this action.

FISCAL IMPACT
This Zoning Ordinance amendment will have no direct impact upon the town budget. In the long term, this proposal will reduce the impact of development upon the town's infrastructure and associated costs.

APPENDIX V

Town of Chatham
Board of Health
Nitrogen Loading Regulation

SECTION 1 AUTHORITY

1.1 The Town of Chatham Board of Health, in accordance with, and under the authority of, Chapter 111, section 31 of the Massachusetts General Laws, does hereby adopt the following rules and regulations.

1.2 The effective date of this regulation shall be September 9, 1991.

1.3 The effective date of the revised regulation is July 22, 2004.

1.4 The effective date of the revised regulation is May 26, 2005.

1.5 The effective date of the revised regulation is May 11, 2006.

SECTION 2 FINDINGS AND PURPOSES

Many houses were built in the Town of Chatham prior to the 1950's at a time when much of the town was developed as a summer retreat. Most of these houses were constructed with individual on-site wells for water supply and individual on-site sewage disposal systems (i.e., cesspools) for wastewater disposal.

Health officials now realize that the on-site soil and hydrological conditions of these lots are in many situations inadequate for sanitary and environmentally safe wastewater disposal. Furthermore, health officials now realize that soil conditions throughout Chatham are generally such that wastewater can migrate rapidly from individual sewage disposal systems to nearby surface waters and well sites.

Inadequately treated wastewater effluent presents various threats to the public health and water quality. Because these threats are better understood today than they were in previous years, many houses and small commercial developments in Chatham could not now be constructed with individual on-site sewage disposal systems under current zoning *bylaws* and health regulations. In Chatham, the minimum lot size permitted for houses with individual on-site sewage disposal systems is currently twenty thousand square feet (20,000 ft^2). This compares with the five thousand to fifteen thousand square foot lots (5,000 ft^2 - 15,000 ft^2) common in older subdivisions.

Health officials now realize that the cumulative impact of numerous adjacent individual on-site sewage disposal systems, given the sandy soil conditions prevalent in Chatham, jeopardizes the quality of ground and surface waters. The effluent from these systems has a high potential of contaminating ground and surface waters. This can lead to closures of shellfishing areas and prohibitions on water contact activities, and have a detrimental effect on the ecosystem. This threat is due not only to contaminants such as fecal coliform bacteria, infectious pathogenic bacteria and viruses, other bacteria associated with fecal discharges, and chemicals from household products, but also to the long-term build-up of nitrates in both ground and surface waters and of phosphorus in surface waters.

Nitrogen compounds found in septic system effluent can cause contamination of drinking water, particularly when systems are located in highly porous sandy soils. Consuming too much nitrate may have serious health consequences. There is strong evidence that nitrate can convert to nitrosamines - known cancer-causing agents. Excessive nitrogen can also produce nutrient loading of surface waters that can result in algae blooms that choke aquatic life. Nitrate contamination is also a "marker" - high concentrations show that other forms of contamination may exist in the water.

The two principal sources of nitrogen contamination and nutrient loading are sewage effluent from individual on-site sewage disposal systems and fertilizers from lawn care practices.

There is increasing pressure in Chatham to expand houses in order to accommodate year-round use and increased seasonal occupancy. This expanded and intensified use increases the discharge of wastewater effluent and increases the threats to the public health and environmental safety from contaminants found in the effluent.

Because of the prevalence of ponds, streams, and other surface water bodies in Chatham, virtually every area of town is critical to protecting the quality of surface and groundwater. Because of the town's reliance on ground water for public and private drinking water, the discharge of wastewater also threatens the quality of drinking water. As a result the BOH voted to declare the entire Town an “Area of Nitrogen Concern” on July 12, 2004.

In order to alleviate the further contamination of ground and surface water resources, and to address threats to the public health that result from wastewater discharge, the Board of Health of the Town of Chatham has determined that immediate measures must be taken. This regulation represents the minimum steps necessary to protect the public health from the adverse effects of the discharge of nitrates and other contaminants from individual on-site sewage disposal systems into the town's ground and surface waters.

SECTION 3 DEFINITIONS

For the purposes of this regulation, the following definitions shall apply:

3.1 MULTI-UNIT HOUSING: Condominiums, apartments, apartments incidental to commercial space, and congregate, cluster, or attached housing where the land is communally owned but the individual units are either owned or rented and where the total Title 5 sewage flow for the lot(s) is less than two thousand (2000) gallons per day. (For developments producing two thousand (2,000) gallons per day or more, the Town of Chatham Sewage Discharge Permit Regulation shall apply.)

3.2 RESIDENTIAL SUBDIVISIONS: Subdivisions as defined in Massachusetts General Law Chapter 41, section 81L, where lots are created and intended for the construction of single-family homes.

3.3 BEDROOM: A room providing privacy intended primarily for sleeping, and consisting of all of the following:

a. floor space of no less than 70 square feet;

b. for new construction, a ceiling height of no less than seven (7) feet three (3) inches;

c. for existing houses, a ceiling height of no less than seven (7) feet;

d. the required ceiling height, as defined in (b.) and (c.) above, cover at least fifty percent (50%) of the required floor area, and that, for sloped ceilings, no part of the required floor area shall have less than five (5) feet in ceiling height;

e. an electrical service and ventilation; and

f. must meet the Minimum Standards of Fitness for Human Habitation (State Sanitary Code, Chapter II, and 105 CMR 410.000).

Living rooms, dining rooms, kitchens, halls, bathrooms, and unfinished cellars, and unfinished, unheated storage areas over garages are not considered bedrooms.

3.4 LOT AREA: An area of land in one ownership that is not a Wetland Resource Area as defined in Sections 3.8.1 and 3.8.2.

3.5 AREA OF NITROGEN CONCERN: Those portions of the mainland area of Chatham where groundwater, the aquifer, and adjacent estuarine environments can be significantly altered by the addition of nitrogen.

3.6 DIVISION OF LAND: The division of a tract of land, including preliminary and definitive subdivisions, Approval Not Required (ANR) plans, Open Space Residential Developments (OSRD), and other legal means, and shall include re-subdivisions. The modification of existing lot lines, not resulting in the creation of new lots, is not subject to this regulation.

3.7 ON-SITE SUBSURFACE SEWAGE DISPOSAL SYSTEM: A system or series of systems for the treatment and disposal of sanitary sewage below the ground surface as defined by 310 CMR 15.000: THE STATE ENVIRONMENTAL CODE, TITLE 5.

3.8 WETLAND RESOURCE AREA:

3.8.1 INLAND WETLAND: Any natural or man-made stream, pond, lake, ditch, or other body of water, wet meadow, marsh, vernal pool, swamp, bog, bank, or areas where groundwater, flowing or standing surface water support a wetland plant community. The delineation of these areas shall be determined in accordance with the Chatham Wetlands Protection Regulations and policies/guidelines. The Conservation Commission may be consulted on the delineation(s).

3.8.2 COASTAL WETLAND: Any coastal bank, coastal beach, coastal dune, saltmarsh, estuary, tidal flat, not including land subject to coastal storm flowage as determined by the 100-year flood plain. Delineation of these areas shall be determined in accordance with the Chatham Wetlands Protection Regulations and policies/guidelines. The Conservation Commission may be consulted on the delineation(s).

SECTION 4 APPLICABILITY

4.1 The following projects shall be subject to the provisions of this regulation:

a. New commercial development with a Title 5 sewage flow under ten thousand (10,000) gallons per day.

b. Existing commercial development with a total Title 5 sewage flow of under ten thousand (10,000) gallons per day where an addition or a change in use is proposed that will increase the sewage flow over the existing flow but still less than ten thousand (10,000) gallons per day

c. Division of Land

i. The creation of a subdivision or Open Space Residential Development (OSRD) of three (3) or more lots or the division of a tract of land into three (3) or more lots shall be served by a shared or common on-site subsurface sewage disposal system that provides nitrogen removal technology. The system may be located anywhere within the subdivision or division, including the open space, if any, subject to all applicable rules, regulations and laws. Subdivisions or OSRDs to be connected to the town sewer are exempt from this provision. Said system shall be constructed in accordance with the Rules and Regulations of the Chatham Sewer Department. In addition, said system shall be so located to maximize future connection to town sewer or other wastewater management facility.

ii. A division of land, involving existing dwelling units, resulting in the creation of parcels which are not in compliance with Section 5.1 of this regulation shall cause each parcel to install an on-site subsurface sewage disposal system that provides nitrogen removal technology. Each parcel affected by this section shall be allowed one additional bedroom upon approval by the Board of Health.

d. Construction of multi-unit housing.

e. Construction of single-family dwellings.

f. Alterations or additions to existing dwellings where a new bedroom is being added.

4.2 Properties already connected to town sewer or that are already using alternative technology that removes nitrogen to the appropriate level for their watershed are exempt from this regulation.

SECTION 5 PROCEDURES

5.1 No Disposal System Construction Permit shall be issued by the Board of Health or its Agents for any of the projects described in Section 4 above unless the proposed system is designed to receive or shall receive four hundred forty (440) gallons per day or less per forty thousand square feet (40,000 ft^2) of lot area.

5.2 No building permit, foundation permit, special permit, or plumbing permit shall be issued for any of the projects described in Section 4 above until a Sewer Entrance Permit or Disposal System Construction Permit has first been obtained, unless the Board of Health, or its agent, determines that the existing sewage disposal system is adequate, including that the system is designed to receive or shall receive four hundred forty (440) gallons per day or less per forty thousand square feet (40,000 ft^2) of lot area.

5.3 On-site subsurface sewage disposal systems for single-family dwellings shall be designed for the actual number of bedrooms present or by that number determined by the Board of Health or its Agent. On-site subsurface sewage disposal systems designed for less than 3 bedrooms shall cause the property to be deed restricted to the actual number of bedrooms present.

5.4 On-site subsurface sewage disposal systems for other than single family dwellings shall be designed for the actual flow.

5.5 Owners and operators of all innovative/alternative sewage treatment technologies, including composting and incinerating toilets and tight tanks, shall report the results of all operation, maintenance, and monitoring activities to Barnstable County Department of Health and Environment. Such reporting must be performed in the manner specified by Barnstable County Department of Health and Environment and must occur within 15 days after each maintenance or monitoring event. Further, when a system operator performs a system inspection and finds that a sewage treatment technology has malfunctioning components which have compromised the system's ability to treat sewage as designed, the operator shall report on the system's status and any planned corrective actions to the Chatham Board of Health and Barnstable County Department of Health and Environment within 48 hours of inspection.

5.6 Any lot reduced in area by the laying out of, and acceptance of, a road or roads as a public way or ways, or for any other municipal purpose serving the common good, shall be allowed to use the area taken in determining compliance with this regulation.

SECTION 6 VARIANCES

6.1 Variances from this regulation may be granted by the Board of Health only if the applicant:

a. demonstrates to the satisfaction of the Board that a literal enforcement of this regulation would involve substantial hardship, financial or otherwise, to the petitioner(s), i.e., would deprive the landowner of all reasonable use of the lot in question, or

b. proves to the Board that the installation of an on-site subsurface sewage disposal system, or systems, would not measurably contribute nitrate to any ground or surface water resource in which there is a threat of contamination due to nitrogen loading or a threat of degradation due to nutrient loading.

6.2 This regulation shall not prohibit the construction of a two (2) bedroom house on any vacant lot providing that said lot is not in a Nitrogen Sensitive Area, as defined in 310 CMR 15.215.

6.3 For residential application the Board may allow, by variance, one (1) additional bedroom over the number allowed by Sections 5.1 or 5.2 with the use of an Innovative/Alternative Technology on-site subsurface sewage disposal system.

6.4 Every request for a variance shall be made in writing and shall state the specific variance sought and the reasons therefore.

No variance shall be granted except after the applicant has notified all abutters by certified mail at his own expense at least ten (10) days before the Board of Health meeting at which the variance request will be on the agenda. The notification shall state the specific variance sought and the reasons therefore.

6.5 If applying for a variance under Subsection 6.1 (a) above, the petitioner shall submit a nitrogen loading report showing several different methods of dealing with the nitrogen load on the property. The petitioner shall also submit written documentation as to why the enforcement of this regulation would cause hardship. The Board reserves the right to require more information of the petitioner in reviewing the variance.

6.6 If applying for a variance under Subsection 6.1 (b) above, the petitioner shall submit, but not be limited to, the following data prepared by a qualified professional: a nitrogen loading report, a hydrogeologic report including direction of ground water flow and depth to ground water, population density and build-out study, soil conditions, topography, and a map showing the position of the lot(s), surrounding surface waters, wetlands, etc., existing and known future water supply wells, buildings, and any other information deemed pertinent. The Board of Health reserves the right to require only approved modeling and input variables for the ground water study.

6.7 The Board of Health will consider, but not be limited to, the following factors when reviewing a variance application:

a. There is a significant setback from surface water resources.

b. There are no present or known future private or public drinking water wells within twenty-five hundred (2500) feet.

c. This applicant has made every effort to be sensitive to environmental resources and balance density and use vs. environmental resources.

d. The implementation schedule of the Comprehensive Wastewater Management Plan.

6.8 Any variance granted by the Board of Health shall be in writing. Any denial of a variance shall also be in writing and shall contain a brief statement of the reasons for the denial. A copy of each variance shall be available to the public at all reasonable hours in the office of the Board of Health while it is in effect.

6.9 Any variance or other modification authorized to be made by this regulation may be subject to such qualification, revocation, suspension, or expiration as the Board of Health expresses in its grant. A variance or other modification authorized to be made by this regulation may otherwise be revoked, modified, or suspended, in whole or in part, only after the holder thereof has been notified in writing and has been given an opportunity to be heard, in conformity with the requirements for an order and hearing as contained in 310 CMR 11.07 and 11.08.

6.10 Any variance or other modification authorized to be made by this regulation is subject to the following condition in the form of a covenant recorded at the Registry of Deeds:

> *"At such time as the Town of Chatham, through its Board of Health and/or Board of Water and Sewer Commissioners, directs the connection of the land herein described to a municipal sewer, the construction of an alternative wastewater treatment system, connection to a shared septic system, or any other wastewater management option for the removal of nitrogen, I, for myself and my Grantees, covenant and agree to comply with such direction. The Board of Health and/or Board of Water and Sewer Commissioners shall determine the schedule for compliance."*

SECTION 7 GENERAL ENFORCEMENT

The provisions of Title 1 of the State Environmental Code (310 CMR 11.00) shall govern the enforcement of this regulation as supplemented herein.

SECTION 8 ORDERS: SERVICE AND CONTENT

8.1 If an examination as provided for in Title 1 (310 CMR 11.00) reveals failure to comply with the provisions of this regulation, the Board of Health shall order the person(s) responsible to comply with the violated provision(s).

8.2 Every order authorized by this regulation shall be in writing. Orders issued shall be served on all persons responsible for the violated provision(s). An order shall be served on the designated person:

a. Personally, by any person authorized to serve civil process, or

b. by any person authorized to serve civil process by leaving a copy of the order at his last and usual place of abode, or

c. by sending him a copy of the order by registered or certified mail, return receipt requested, if he is within the Commonwealth, or

d. if his last and usual place of abode is unknown or outside the Commonwealth, by posting a copy of the order in a conspicuous place on or about the affected premises and by advertising it for at least three (3) out of five (5) consecutive days in one or more newspapers of general circulation within the municipality wherein the building or premises affected is situated.

8.3 Subject to the emergency provision of Title 1, any order issued under the provisions of this regulation shall;

a. Include a statement of the violation or defect, and may suggest action which, if taken, will effect compliance with this regulation,

b. allot a reasonable time for any action it requires, and

c. inform the person to whom it is directed of his right to a hearing, of his responsibility to request the hearing, the time frame in which the response must be made, and to whom the request shall be directed.

SECTION 9 HEARING

9.1 Unless otherwise specified in this regulation, the person or persons to whom any order has been served pursuant to this regulation may request a hearing before the Board of Health by filing with the Board of Health within seven (7) days after the day the order was served, a written petition requesting a hearing on the matter. Upon receipt of such petition, the Board of Health shall set a time and place for a hearing and shall inform the petitioner thereof in writing. The hearing shall be held not later than thirty (30) days after the day on which the order was served. The Board of Health, upon application of the petitioner, may postpone the date of the hearing for a reasonable time beyond such thirty day (30) period if in the judgment of the Board of Health the petitioner has submitted a good and sufficient reason for such postponement.

9.2 At the hearing, the petitioner shall be given an opportunity to be heard and to show because why the order should be modified or withdrawn.

9.3 After the hearing, the Board of Health shall sustain, modify, or withdraw the order and shall inform the petitioner in writing of its decision. If the Board of Health sustains or modifies the order, it shall be carried out within the time period allotted in the original order or in the modification.

9.4 Every notice, order, or other record prepared by the Board of Health in connection with the hearing shall be entered as a matter of public record in the office of the Board of Health.

9.5 If written petition for a hearing is not filed with the Board of Health within seven (7) days after the day the order has been served or if after the hearing the order has been sustained in any part, each day's failure to comply with the order as issued or modified shall constitute a separate offense.

SECTION 10 APPEAL

Any person aggrieved by the final decision of the Board of Health may seek relief therefrom within thirty (30) days in any court of competent jurisdiction, as provided by the laws of the Commonwealth.

SECTION 11 PENALTIES

11.1 Any person who shall violate any provision of this regulation for which penalty is not otherwise provided in any of the General Laws or in any other provision of this regulation or Title 1 of the State Environmental Code shall, upon conviction, be fined not less than ten (10) nor more than five hundred (500) dollars.

11.2 Any person who shall fail to comply any order issued pursuant to the provisions of this regulation shall, upon conviction, be fined not less than ten (10) nor more than five hundred (500) dollars. Each day's failure to comply with an order shall constitute a separate offense.

SECTION 12 SEVERABILITY

If any title, regulation, section, paragraph, sentence, clause, phrase, or word of this code shall be declared invalid for any reason whatsoever, that decision shall not affect any other portion of this code or regulation, which shall remain in full force and effect; and to this end the provisions of this code and regulation are hereby declared severable.

APPENDIX W

MassDEP Guidelines on Inter-Municipal Collaboration Financing

An estuary is a natural system that does not follow town boundaries. With the exception of Nantucket, every town in the MEP shares at least one estuary with one or more other towns. To restore the health of their estuaries, collaboration among all the towns in the watershed is important for several reasons:

- Nitrogen pollution does not follow town boundaries. It comes from many different sources and from the entire watershed, including areas that don't border the water. Septic systems, treatment plants, stormwater and fertilizer from virtually anywhere in MEP towns add to nitrogen pollution in their estuary.
- Watershed-based calculations are the most accurate way to factor in all point and nonpoint sources of pollution.
- Looking at solutions over the entire watershed is the best way to identify the most cost-effective and environmentally-effective plan to restore the estuary. The most practical solutions are likely to be shared actions by towns, paid for by everyone in the watershed.
- All important stakeholders need to be at the table when decisions are made, regardless of their town or where they live: on the water, near a stream or pond, or in upland areas.

Building a collaborative relationship across town borders and among diverse interest groups is an opportunity for towns to think and act differently. In some estuaries, they will be able to take advantage of existing watershed groups, and in others, can build on already successful intermunicipal relationships, for example, around a shared school or wastewater treatment facility. Nonprofit groups, regional organizations and individual facilitators can help towns work on these shared issues.

MassDEP's 2003 Implementation Guidance (http://www.mass.gov/dep/water/resources/mepmain.pdf) outlines a number of areas that towns need to address in the restoration process. These guidelines offer input in three additional areas:

1. Coordinating planning and implementation
2. Deciding the most cost-effective and environmentally appropriate restoration scenario
3. Sharing the cost of restoration among towns

1. Coordinating Planning and Implementation

A watershed-wide nitrogen management plan is the ideal option for coordinated planning and implementation. It might be structured in several ways:

- A watershed-based Plan written specifically for a group of towns.
- One document that pulls together relevant information from plans of several towns.
- One town's plan that addresses watershed-wide issues and contains input from other towns in the watershed.

For example, six communities in the Assabet River watershed, each of which is developing its own plan, formed a Consortium to study common wastewater issues and prepare one coordinated plan to reduce phosphorus pollution in the Assabet River. Individually, the towns had lower priority points for SRF funding. However, their joint proposal ranked higher on the priority list, and MassDEP awarded SRF funds for both the local and basin-wide plans.

Although shared planning is easiest for towns all starting their planning at the same time, most MEP towns are at different stages of planning. In these cases, coordination is even more important, and towns can take a number of steps:

- Begin talking together early in the process, by jointly reviewing the MEP Technical Reports and TMDL, discussing shared concerns, and even submitting joint comments on the Technical Report. Discussions and decisions about cost-sharing can happen regardless of whether towns are in the formal planning process
- Schedule inter-municipal briefings on the MEP and Technical Reports.
- Discuss nitrogen attenuation options and request model runs based on input from all towns.
- Coordinate formal planning and construction schedules where possible, or at least share information on individual plans.
- When formal planning begins, appoint Citizens' Advisory Committee (CAC) members from other towns that share the estuary, as Mashpee has done.
- Create a joint written record of mutual decisions and a schedule of key points down the road at which coordination will be needed.
- For towns planning to include a number of estuaries in a town-wide plan, pursue implementation in watersheds solely within their town boundaries and hold off on final decisions in shared watersheds.

Towns ready to move ahead with planning and implementation don't have to wait until all towns in the estuary are ready to begin planning. Towns that do not collaborate in the planning process may find that their options down the road are limited by decisions made by the towns that began working together early in the process.

2. Deciding the most cost-effective and environmentally appropriate restoration plan

There are many ways to meet an estuary's nitrogen Total Maximum Daily Load (TMDL). The most cost-effective and environmentally appropriate restoration plan will depend on the many local factors documented in each Technical Report. These factors include how much nitrogen comes from septic and on-site systems as well as from treatment plants, stormwater, and fertilizers, the extent of natural attenuation, and local geography and hydrodynamics.

As a starting point for local discussion of restoration alternatives, each estuary's Technical Report includes one hypothetical scenario that estimates how much nitrogen from septic systems would need to be removed from the watershed in order to meet the nitrogen TMDL and biological thresholds. This hypothetical scenario is not a recommendation by SMAST or MassDEP, nor does it have the level of detail needed for facilities planning. That's why towns will use additional modeling during their planning to evaluate the details of the many possible ways to reduce nitrogen and meet the TMDL.

It is premature for MassDEP to decide solutions a town or towns should use to meet the estuary TMDL, for several reasons:

- The Technical Report scenario is a hypothetical scenario, and the approach it uses may not be the most cost-effective one when all options are studied.

- An accurate and fair calculation of load reductions depends upon information and decisions that only towns can provide: future land use and pace of development, land banking efforts, and other nitrogen reduction solutions that towns may want to pursue. For any reduction scenario, the relevant variables for each town must be combined and their interactions modeled to determine if the TMDL is achieved. Towns are likely to need multiple rounds of modeling to determine and agree on the best scenario for their estuary.

- Different scenarios will likely apportion load reductions in very different ways among subwatersheds and towns. Towns are the best decision-makers as to which of the many possibilities is most practical and acceptable.

3. Sharing the cost of restoration among towns

Agreement among towns on how to share the cost of restoration is a decision that MassDEP urges towns to make separately from their consideration of the most cost-effective and environmentally appropriate restoration scenario. MassDEP offers the guidelines below for this decision and will meet with towns to talk about the pros and cons of particular cost-sharing methods, but the decisions on cost-sharing will be made by towns themselves.

Guideline #1: Agree first on criteria for choosing a cost sharing method. Fairness, logic, transparency, and public acceptability are some of the key principles to consider in evaluating different methodologies.

Guideline #2: Start with information provided by MEP. As the Technical Report for each estuary is completed, the MEP will calculate the amount of nitrogen that originates in each town, based on current land use loadings and assumptions of natural attenuation contained in the Technical Report. Sharing costs among towns based on their relative share of nitrogen contributions to the estuary is a reasonable starting point for local discussions, but is not the only method that could be used.

Guideline #3: Consider other cost-sharing methods. Some other factors to consider are relative acreage, population, tax base, location near the estuary, and the percentage reductions required. Towns may want to combine more than one factor into a cost-sharing formula. Some examples of cost allocation and sharing follow:

- The Blackstone Lakes (Massachusetts) TMDL for phosphorus is based on an equal percentage reduction in contributions by nonpoint sources.
- Stakeholders in the Chesapeake Bay based their allocations on both contributions of nitrogen and benefit from restoration. A full description of the Chesapeake decisions and decision-making process is at http://chesapeakebay.net/caploads.htm.
- Equal yearly percentage reductions in nitrogen were used to allocate loads to the 79 wastewater treatment plants in the Long Island Sound Study. For more information: http://www.longislandsoundstudy.net/
- The MWRA allocates its capital costs with a formula that combines population and three-year average water flows.

A general source of information on allocations and cost-sharing is EPA's Guidance for Water Quality-Based Decisions: The TMDL Process (http://www.epa.gov/OWOW/tmdl/decisions/), which describes allocation methodologies for point sources. Although conditions in MEP towns differ from those in watersheds dominated by point source pollution, the process described in this guidance may be helpful.

Some MEP towns have also discussed build-out loads as a basis for cost sharing. This is possible, but it is essential to remember that any projections of growth and additional nitrogen loadings will need to take account of the very large reductions in current nitrogen loading needed to meet TMDLs - between 60-80% of current loads in most estuaries. A majority of the nitrogen in MEP watersheds comes from septic systems.

Guideline #4: Consider trading programs. Once towns have agreed on their preferred restoration strategy and a cost-sharing formula, towns can consider intermunicipal and inter-facility water quality trading. For example, the most cost-effective scenario for the watershed as a whole may concentrate wastewater treatment facilities in a few subwatersheds closest to the estuary. But all towns whose wastewater is treated at the plant can share in the costs of the facility based on the formula they have accepted. Water quality trading is covered in more detail in a separate section of this Guidance, as well as in EPA's Water Quality Trading Assessment Handbook: http://www.epa.gov/owow/watershed/trading/handbook.

APPENDIX X

2008 Environmental Bond Bill (Clean Water) Legislation

Adopted legislation to modify the request for SRF funding to meet Cape Cod's needs (http://www.mass.gov/legis/bills/house/185/ht05pdf/ht05054.pdf (p.47)) under the 2008 Environmental Bond Bill (see: http://www.mass.gov/legis/laws/seslaw08/sl080312.htm).

SECTION 1. Chapter 83 of the General Laws is hereby amended by adding the following new sections:

SECTION 1A. Notwithstanding the provisions of sections 1 and 3 of chapter 83 of the General Laws to the contrary, any municipality or sewer district adopting this section is hereby authorized to lay out, construct, maintain and operate a system or systems of common sewers and main drains in public or private ways for that part of its territory as it adjudges necessary to reduce or eliminate the impacts of nutrient enrichment on surface water bodies or sources of drinking water with such connections and other works as may be required for a system or systems of sewerage and drainage, and sewage treatment and disposal. Adoption of this section is subject to majority vote of the municipality and subject further to said municipality having an approved Comprehensive Water Resources Management Plan (CWMP), as defined by the Department of Environmental Protection (DEP).

SECTION 1B. At the commencement of operation of the municipalities' sewer system authorized by section 1A of chapter 83 of the General Laws, the owner of land abutting upon a private or public way in which a common sewer has been laid shall be required by the board or officer having charge of the maintenance and repair of sewers to connect such land with a common sewer only if the land in question is within the area(s) identified in the department of environmental protection-approved CWMP and has been specifically identified in the plan as requiring wastewater collection and treatment for flows in existence on said properties at the time of adoption of this act in order to protect surface waters or drinking water resources from the effects of nutrient enrichment; or the on-site subsurface sewage disposal system serving said land fails to comply with the provisions of 310 CMR 15.000, et seq. and an on-site subsurface sewage disposal system cannot be constructed on the property in compliance with said regulations and an enhanced treatment system under remedial use cannot be designed and constructed to adequately treat sewage from said property; or to service housing of which at least 15 per cent of the housing units are deed restricted to residents with incomes no greater than 80 per cent of the area median income paying no more than 30 per cent of their income towards housing. The town shall not allow an abutting property owner utilizing an enhanced treatment system under remedial use to opt out of connecting to the sewer system unless the town implements a monitoring and inspection plan approved by the department of environmental protection for such remedial system or systems. Such plan may include the assessment of a reasonable fee by the board of health to implement the monitoring and inspection plan.

Notwithstanding any provision of sections 1 and 3 to the contrary, owners of land not identified in the CWMP as needing to be connected to the municipal treatment works shall not be permitted to connect to the sewer system. Said plan may be amended from time to time by the board or officer having charge of sewers, after a public hearing conducted to consider such amendment, and upon approval of the department of environmental protection. The board or officer having charge of sewers shall adopt regulations within 120 days after the adoption of this act establishing publication and notification procedures to carry out the purposes of this section.

SECTION 1C. After commencement of operations of the sewer system authorized pursuant to section 1A, additional connections shall be permitted within the final area of concern by such board or officer having charge of the maintenance and repair of sewers, subject to available capacity, only upon certification by the board of health that the on-site subsurface sewage disposal system on land abutting upon a private or public way in which a common sewer has been laid cannot comply with the provisions of 310 CMR 15.000, et seq., or in the case of new construction, expansion of an existing structure, a change in use, or increases in flow from said land, such expansion, change in use, or increase in flow does not result in sewage flow in excess of the amount of said regulations flow capacity or actual flow resulting from a legal use of said land, whichever is greater, which existed on the date of adoption of this act as determined by the board of health. Notwithstanding anything to the contrary contained herein, the board or officer having charge of the maintenance and repair of sewers may at any time permit extensions, new connections or increases in flow to the sewer system, subject to capacity, to serve municipal buildings, public restrooms, or other public service uses, including but not limited to housing of which at least 15 per cent of the housing units are deed restricted to residents with incomes no greater than 80 per cent of the area median income paying no more than 30 per cent of their income towards housing.

SECTION 1D. Notwithstanding the provisions of chapters 80 and 83 of the General Laws to the contrary, a municipality acting under section 1A may make assessments upon owners of land abutting upon a private or public way in which a common sewer has been laid only at the time of actual connection to the common sewer. Nothing herein shall preclude the town from making estimated sewer assessments pursuant to section 15B. The municipality may make equitable adjustments to the annual charges established pursuant to section 16 for the use of common sewers by owners of land who connect under this act for the purpose of insuring an equitable distribution of the total sewer system costs, including assessments and sewer use charges.

SECTION 1E. Every decision by the board or officer having charge of sewers permitting or denying a connection to the sewer system pursuant to sections 1A to 1D, inclusive shall be made in writing. Any person aggrieved by such a decision may appeal said decision within 30 days of issuance pursuant to the provisions of section 14 of chapter 30A.

SECTION 1F. In carrying out the provisions of sections 1A to 1E, inclusive, a municipality shall not discriminate against any person on the grounds of race, color, marital status, physical disability, age, sex, sexual orientation, religion, ancestry or national origin in any manner prohibited by federal or state law.

SECTION 1G. Notwithstanding the provisions of any general or special law to the contrary, a municipality with a comprehensive water resources management plan under review or approved by the department of environmental protection may establish and maintain a separate account into which it may collect and deposit and expend funds from property owners for the difference in cost between a conventional subsurface wastewater disposal system as required in 310 CMR 15.00, et seq, and the cost of a subsurface wastewater disposal system designed to reduce the nitrogen discharge from said system as long as the property in question is identified in the CWMP as being a priority for the installation of a wastewater collection and treatment system for the purposes of reducing the impacts of excessive nitrogen on marine waters and drinking water supplies. Funds from this account may be used only for the purpose of the construction, maintenance and operation of said wastewater treatment and collection works and shall be applied to toward the costs of connection and or betterment assessed to the property(s) in question.