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.

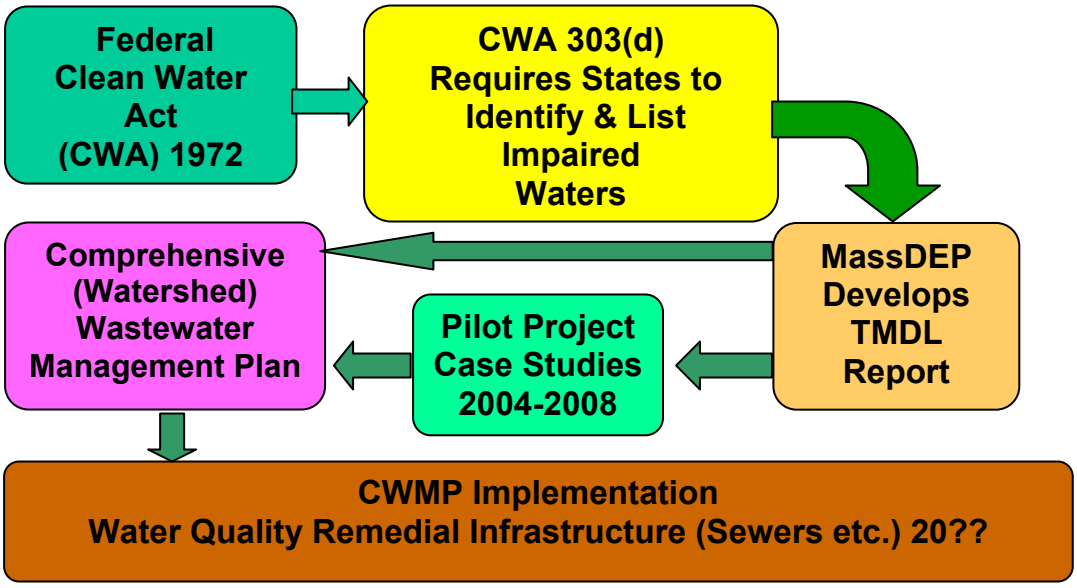

Figure 1.3 Diagram Defining the Pilot Project Case Studies Role in the Implementation of a TMDL

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, strormwater 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.

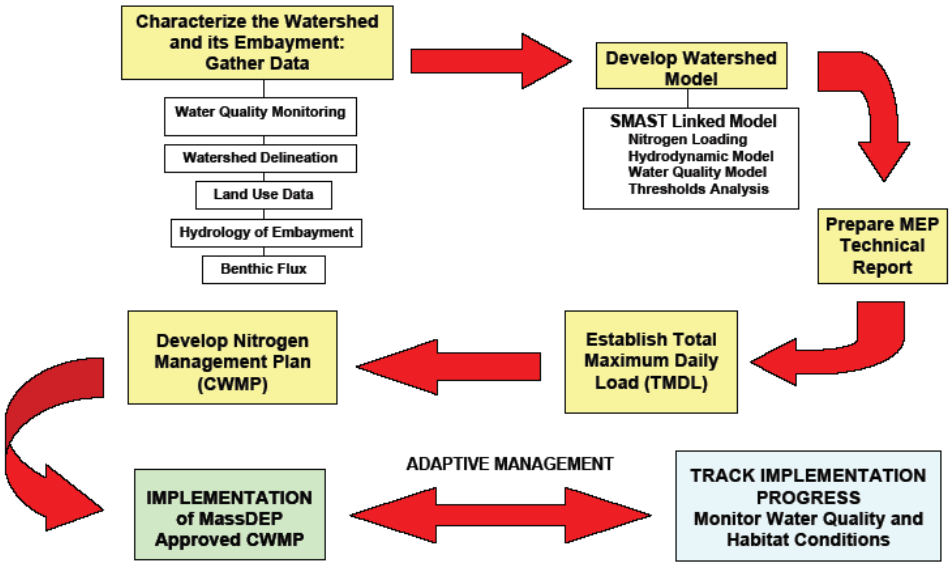

Figure 1.4: The Massachusetts Estuary Project Restoration Process

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