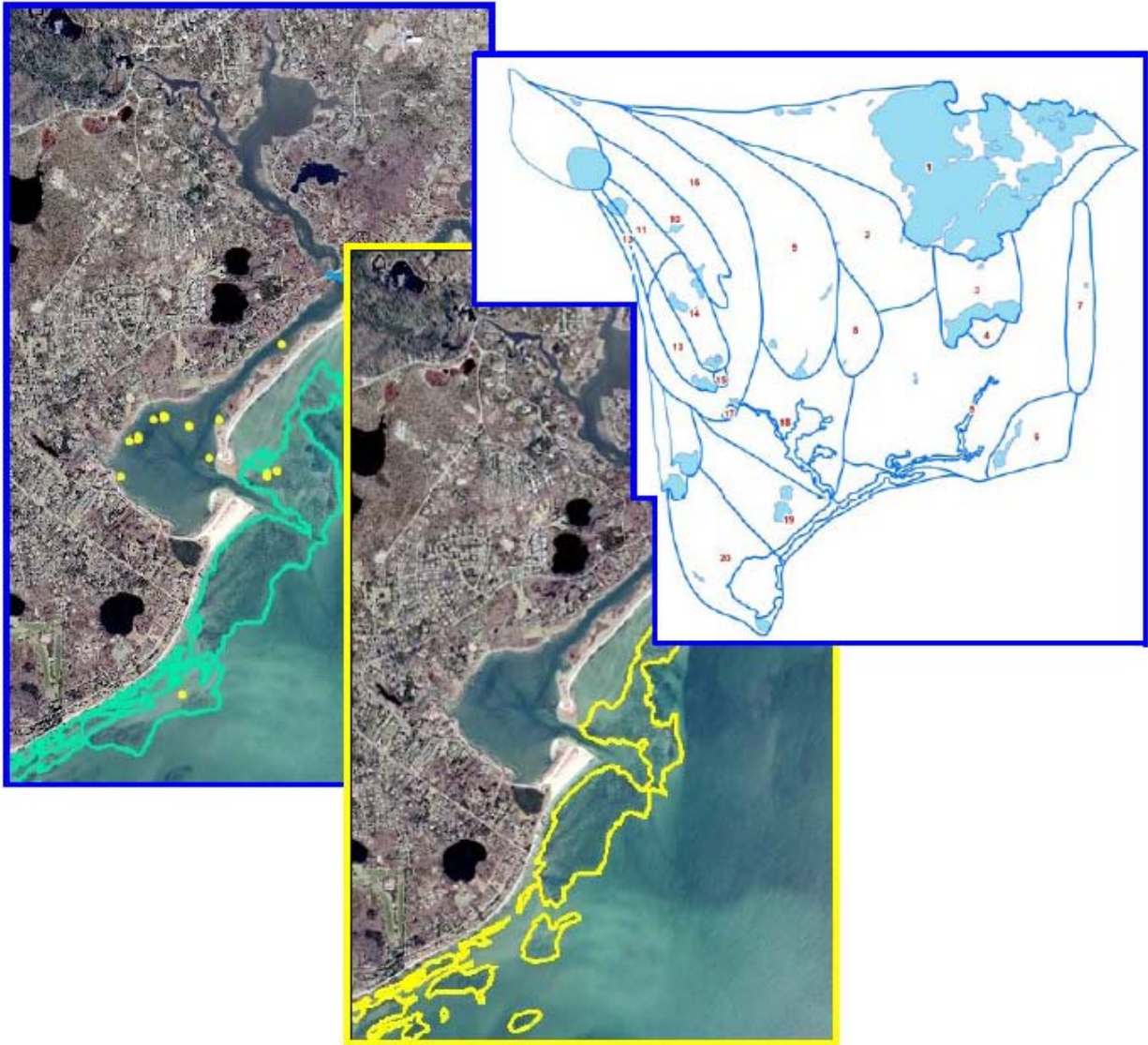


**FINAL**  
**Centerville River - East Bay System**  
**Total Maximum Daily Loads**  
**For Total Nitrogen**

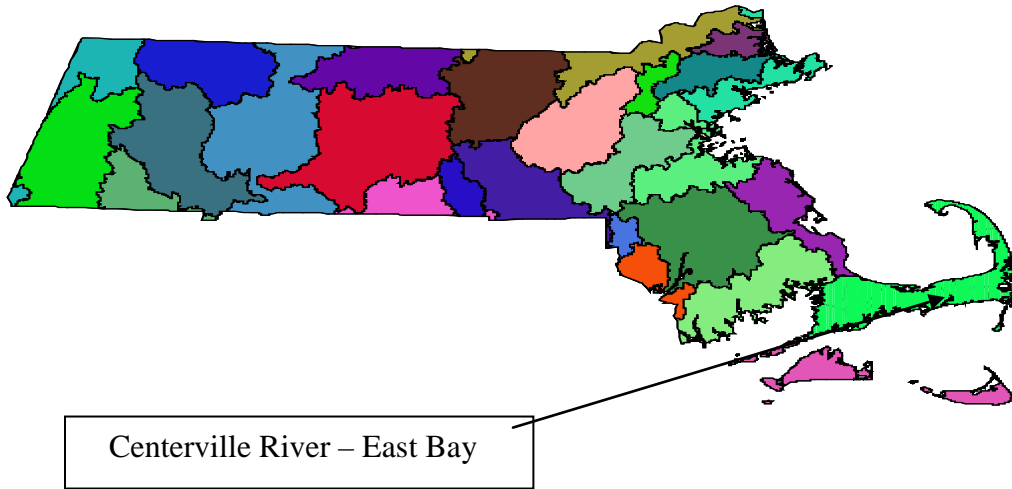
(Report # 96-TMDL-14 Control #248.0)



**COMMONWEALTH OF MASSACHUSETTS**  
**EXECUTIVE OFFICE OF ENERGY AND ENVIRONMENTAL AFFAIRS**  
IAN A. BOWLES, SECRETARY  
**MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION**  
LAURIE BURT, COMMISSIONER  
ARLEEN O'DONNELL DEPUTY COMMISSIONER  
**BUREAU OF RESOURCE PROTECTION**  
GLENN HAAS, ACTING ASSISTANT COMMISSIONER

December 18, 2007

**Centerville River - East Bay  
Total Maximum Daily Loads  
For Total Nitrogen**



**Key Feature:** Total Nitrogen TMDL for Centerville River – East Bay

**Location:** EPA Region 1

**Land Type:** New England Coastal

**303d Listing:**

The waterbody segments impaired and on the Category 5 list include Centerville River.

**Data Sources:** University of Massachusetts – Dartmouth/School for Marine Science and Technology; US Geological Survey; Applied Coastal Research and Engineering, Inc.; Cape Cod Commission, Town of Barnstable.

**Data Mechanism:** Massachusetts Surface Water Quality Standards, Ambient Data, and Linked Watershed Model

**Monitoring Plan:** Town of Barnstable monitoring program (possible assistance from SMAST)

**Control Measures:** Sewering, Storm Water Management, Attenuation by Impoundments and Wetlands, Fertilizer Use By-laws

# EXECUTIVE SUMMARY

## Problem Statement

Excessive nitrogen (N) originating primarily from on-site wastewater disposal (both conventional septic systems and innovative/alternative systems) has led to significant decreases in the environmental quality of coastal rivers, ponds, and harbors in many communities in southeastern Massachusetts. In the Town of Barnstable the problems in coastal waters include:

- Loss of eelgrass beds, which are critical habitats for macroinvertebrates and fish
- Undesirable increases in macro algae, which are much less beneficial than eelgrass
- Periodic extreme decreases in dissolved oxygen concentrations that threaten aquatic life
- Reductions in the diversity of benthic animal populations
- Periodic algae blooms

With proper management of nitrogen inputs these trends can be reversed. Without proper management more severe problems might develop, including:

- Periodic fish kills
- Unpleasant odors and scum
- Benthic communities reduced to the most stress-tolerant species, or in the worst cases, near loss of the benthic animal communities

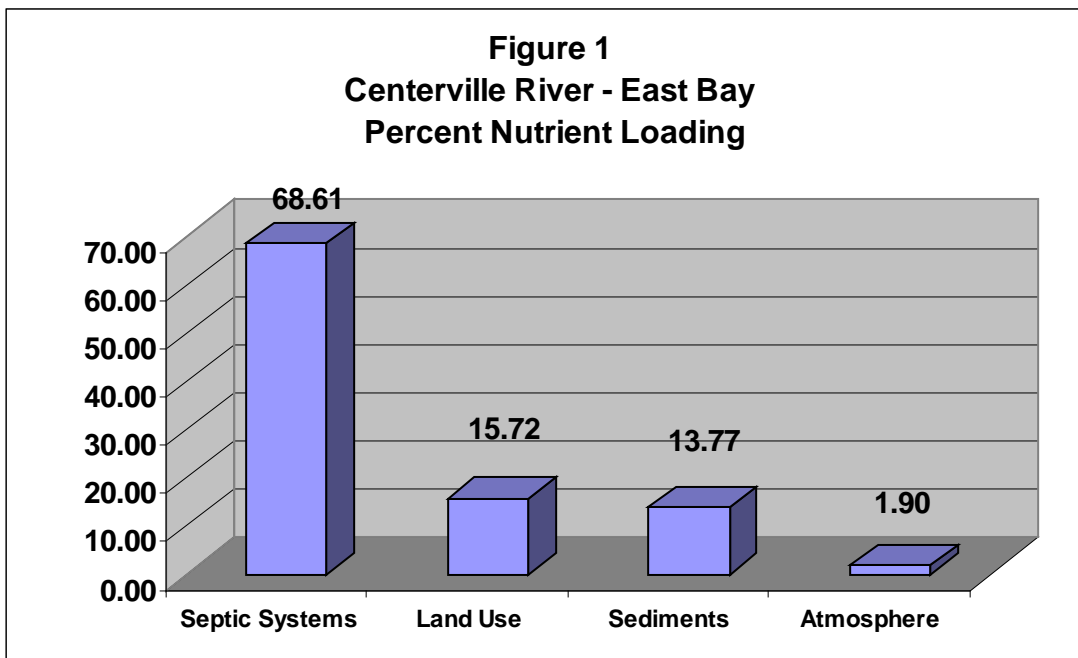
Coastal communities, including Barnstable; rely on clean, productive, and aesthetically pleasing marine and estuarine waters for tourism, recreational swimming, fishing, and boating, as well as for commercial fin fishing and shellfishing. Failure to reduce and control N loadings may result in complete replacement of eelgrass by macro-algae, a higher frequency of extreme decreases in dissolved oxygen concentrations and fish kills, widespread occurrence of unpleasant odors and visible scum, and a complete loss of benthic macroinvertebrates throughout most of the embayments. As a result of these environmental impacts, commercial and recreational uses of Centerville River - East Bay System coastal waters will be greatly reduced, and could cease altogether.

## Sources of nitrogen

Nitrogen enters the waters of coastal embayments from the following sources:

- The watershed
  - On-site subsurface wastewater disposal systems
  - Natural background
  - Runoff
  - Fertilizers
  - Wastewater treatment facilities
- Atmospheric deposition
- Nutrient-rich bottom sediments in the embayments

Most of the present controllable N load originates from individual subsurface wastewater disposal (septic) systems, primarily serving individual residences, as seen in the following figure.



### Target Threshold Nitrogen Concentrations and Loadings

The N loadings (the quantity of nitrogen) to this embayment system ranges from 22.46 kg/day in East Bay, to 81.01 kg/day in Centerville River. The resultant concentrations of N in these subembayments range from 0.33 mg/L (milligrams per liter of nitrogen) in Bumps River to 0.79 mg/L in Centerville River.

In order to restore and protect this system, N loadings, and subsequently the concentrations of N in the water, must be reduced to levels below the threshold concentrations that cause the observed environmental impacts. This concentration will be referred to as the target threshold N concentration. It is the goal of the TMDL to reach this target threshold N concentration, as it has been determined for each impaired waterbody segment. The Massachusetts Estuaries Project (MEP) has determined that, for this embayment system, N concentration of 0.37 mg/L is protective. The mechanism for achieving these target threshold N concentrations is to reduce the N loadings to the embayments. The Massachusetts Estuaries Project (MEP) has determined that the Total Maximum Daily Loads (TMDL) of N that will meet the target thresholds range from 22 to 53 kg/day. This document presents the TMDLs for each impaired water body segment and provides guidance to the affected town on possible ways to reduce the nitrogen loadings to within the recommended TMDL, and protect the waters for these waterbodies.

### Implementation

The primary goal of implementation will be lowering the concentrations of N by greatly reducing the loadings from on-site subsurface wastewater disposal systems through a variety of centralized or decentralized methods such as sewerage and treatment with nitrogen removal technology, advanced treatment of septage, upgrade/repairs of failed on-site systems, and/or installation of N-reducing on-site systems.

These strategies, plus ways to reduce N loadings from stormwater runoff and fertilizers, are explained in detail in the “MEP Embayment Restoration Guidance for Implementation Strategies”, that is available on the MassDEP website at (<http://www.mass.gov/dep/water/resources/restore.htm>). The appropriateness of any of the alternatives will depend on local conditions, and will have to be determined on a case-by-case basis, using an adaptive management approach.

Finally, growth within the communities of Barnstable that would exacerbate the problems associated with N loadings, should be guided by considerations of water quality-associated impacts.

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## Introduction

Section 303(d) of the Federal Clean Water Act requires each state (1) to identify waters for which effluent limitations normally required are not stringent enough to attain water quality standards and (2) to establish Total Maximum Daily Loads (TMDLs) for such waters for the pollutants of concern. The TMDL allocation establishes the maximum loadings (of pollutants of concern), from all contributing sources, that a water body may receive and still meet and maintain its water quality standards and designated uses, including compliance with numeric and narrative standards. The TMDL development process may be described in four steps, as follows:

1. Determination and documentation of whether or not a water body is presently meeting its water quality standards and designated uses.
2. Assessment of present water quality conditions in the water body, including estimation of present loadings of pollutants of concern from both point sources (discernable, confined, and concrete sources such as pipes) and non-point sources (diffuse sources that carry pollutants to surface waters through runoff or groundwater).
3. Determination of the loading capacity of the water body. EPA regulations define the loading capacity as the greatest amount of loading that a water body can receive without violating water quality standards. If the water body is not presently meeting its designated uses, then the loading capacity will represent a reduction relative to present loadings.
4. Specification of load allocations, based on the loading capacity determination, for non-point sources and point sources, which will ensure that the water body will not violate water quality standards.

After public comment and final approval by the EPA, the TMDL will serve as a guide for future implementation activities. The MassDEP will work with the Towns to develop specific implementation strategies to reduce N loadings, and will assist in developing a monitoring plan for assessing the success of the nutrient reduction strategies.

In the Centerville River - East Bay System, the pollutant of concern for these TMDLs (based on observations of eutrophication), is the nutrient N. Nitrogen is the limiting nutrient in coastal and marine waters, which means that as its concentration is increased, so is the amount of plant matter. This leads to nuisance populations of macro-algae and increased concentrations of phytoplankton and epiphyton that impair eelgrass beds and imperil the healthy ecology of the affected water bodies.

The TMDLs for N in the Centerville River - East Bay System are based primarily on data collected, compiled, and analyzed by University of Massachusetts Dartmouth's School of Marine Science and Technology (SMAST), the Cape Cod Commission, and others, as part of the Massachusetts Estuaries Project (MEP). The data were collected over a study period from 2001 to 2005. This study period will be referred to as the "Present Conditions" in the TMDL since it contains the most recent data available. The accompanying MEP Technical Report can be found at <http://www.oceanscience.net/estuaries/reports.htm>. This report presents the results of the

analyses of this coastal embayment system using the MEP Linked Watershed-Embayment Nitrogen Management Model (Linked Model). The analyses were performed to assist the Towns with decisions on current and future wastewater planning, wetland restoration, anadromous fish runs, shellfisheries, open-space, and harbor maintenance programs. A critical element of this approach is the assessment of water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure that was conducted on each embayment. These assessments served as the basis for generating N loading thresholds for use as goals for watershed N management. The TMDLs are based on the site specific thresholds generated for each embayment. Thus, the MEP offers a science-based management approach to support the wastewater management planning and decision making process in the Towns of Barnstable.

## Description of Water Bodies and Priority Ranking

The Centerville River - East Bay System in Barnstable Massachusetts, at the southeastern edge of Cape Cod, faces Nantucket Sound to the south, and consists of a number of subembayments of varying size and hydraulic complexity, characterized by limited rates of flushing, shallow depths and heavily developed watersheds (see Figures 2 and 3 below). This system constitutes an important component of the Town's natural and cultural resources. The nature of enclosed embayments in populous regions brings two opposing elements to bear: 1) as protected marine shoreline they are popular regions for boating, recreation, and land development and 2) as enclosed bodies of water, they may not be readily flushed of the pollutants that they receive due to the proximity and density of development near and along their shores. In particular, the subembayments within the Centerville River - East Bay System are at risk of further eutrophication from high nutrient loads in the groundwater and runoff from their watersheds. Waterbody segments within this system are already listed as waters requiring TMDLs (Category 5) in the MA 2006 Integrated List of Waters, as summarized in Table 1A. Although not presently listed for nutrient impairment, recent data collected as part of the MEP overall effort indicates that the Centerville River and Scudder Bay are moderately impaired due to nutrients and as such need to be addressed in this TMDL.

**Table 1A. The Centerville River - East Bay System Waterbody Segments  
in Category 5 of the Massachusetts 2006 Integrated List<sup>1</sup>**

NAME	WATERBODY SEGMENT	DESCRIPTION	SIZE	POLLUTANT LISTED
<b>Centerville River - East Bay System</b>				
Centerville River	MA96-04_2006	From headwaters in wetland west of Strawberry Hill Road to confluence with Centerville Harbor, including East Bay, Barnstable.	0.25 sq mi	-Pathogens
Bumps River	MA96-02_2006	From outlet of pond at Bumps River Road through Scudder Bay to South Main Street bridge (confluence with Centerville River), Barnstable	0.07 sq mi	-Pathogens



A complete description of this embayment system is presented in Chapters I and IV of the MEP Technical Report, which is available at <http://www.oceanscience.net/estuaries/reports.htm>. A majority of the information on this embayment system is drawn from this report. Chapters VI and VII of the MEP Technical Report provide assessment data that show that the Centerville River - East Bay embayment system is impaired because of excess nutrients, loss of eelgrass, low dissolved oxygen levels, elevated chlorophyll *a* levels, and benthic fauna habitat degradation. Please note that pathogens are listed in Tables 1A for completeness. Further discussion of pathogens is beyond the scope of this TMDL.

The embayment addressed by this document is determined to be a high priority based on three significant factors: (1) the initiative that the Town has taken to assess the conditions of the entire embayment system, (2) the commitment made by the Town to restore and preserve the embayment, and (3) the extent of impairment in the embayment. In particular, this embayment is at risk of further degradation from increased N loads entering through groundwater and surface water from their increasingly developed watersheds. In both marine and freshwater systems, an excess of nutrients results in degraded water quality, adverse impacts to ecosystems, and limits on the use of water resources. The general conditions related to the major indicators of habitat impairment, due to excess nutrient loading, are summarized and tabulated in Table 1B. Observations are summarized in the Problem Assessment section below, and detailed in Chapter VII, Assessment of Embayment Nutrient Related Ecological Health, of the MEP Technical Report.

Figure 2 Overview of Centerville River - East Bay, Barnstable



**Table 1B. General summary of conditions related to the major indicators of habitat impairment observed in the Centerville River - East Bay embayment systems.**

Centerville River - East Bay System	Eelgrass Loss <sup>1</sup>	Dissolved Oxygen Depletion	Chlorophyll <i>a</i> <sup>2</sup>	Macro-algae	Benthic Fauna <sup>3</sup>
Centerville River	SI	<6 mg/L up to 36% of time <4 mg/L up to 8% of time GF-MI	>10 ug/L up to 71% of time >20 ug/L up to 41% of time GF-MI	GF-MI	GF-MI
East Bay	SI	<6 mg/L up to 55% of time MI	>5 ug/L up to 43% of time >10 ug/L up to 10% of time GF	GF	MI
Bumps River	NS	MI	Insufficient Data	GF	GF
Scudder Bay	NS	<6 mg/L up to 19% of time <4 mg/L up to 1% of time MI	>10 ug/L up to 70% of time >20 ug/L up to 31% of time MI	MI	MI

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 – Severe Degraded – critically or harshly changed from normal conditions\*

NS - Non-supportive habitat. No eelgrass was present in 1951 Survey data.

\* - These terms are more fully described in MEP report “Site-Specific Nitrogen Thresholds for Southeastern Massachusetts Embayments: Critical Indicators”

December 22, 2003 <http://www.mass.gov/dep/water/resources/coastalr.htm>.

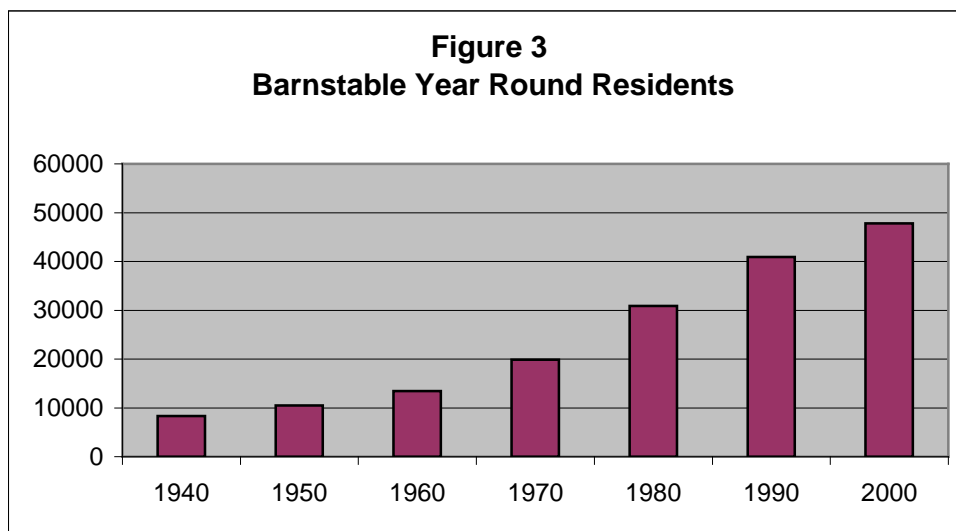
## Problem Assessment

The watershed of Centerville River - East Bay embayment has had rapid and extensive development of single-family homes and the conversion of seasonal into full time residences. This is reflected in a substantial transformation of land from forest to suburban use between the years 1950 to 2000. Water quality problems associated with this development result primarily from on-site wastewater treatment systems, and to a lesser extent, from runoff - including fertilizers - from these developed areas.

On-site subsurface wastewater disposal system effluents discharge to the ground, enter the groundwater system and eventually enter the surface water bodies. In the sandy soils of Cape Cod, effluent that has entered the groundwater travel towards the coastal waters at an average rate of one foot per day. The nutrient load to the groundwater system is directly related to the number of subsurface wastewater disposal systems, which in turn are related to the population. The population of Barnstable, as with all of Cape Cod, has increased markedly since 1950. In the period from 1950 to 2000 the number of year round residents has almost quadrupled. In addition, summertime residents and visitors swell the population of the entire Cape by about 300% according to the Cape Cod Commission <http://www.capecodcommission.org/data/trends98.htm#population>).

Prior to the 1950's there were few homes and many of those were seasonal. During these times water quality was not a problem and eelgrass beds were plentiful. Dramatic declines in water quality, and the quality of the estuarine habitats, throughout Cape Cod, have paralleled its population growth since these times. The problems in these particular sub-embayments generally include periodic decreases of dissolved oxygen, decreased diversity and quantity of benthic animals, and periodic algal blooms. Eelgrass beds, which are critical habitat for macroinvertebrates and fish, have completely disappeared from these waters. Furthermore, the eelgrass was replaced by macroalgae, which are undesirable, because they do not provide high quality habitat for fish and invertebrates. In the most severe cases habitat degradation could lead 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.

Coastal communities, including Barnstable, rely on clean, productive, and aesthetically pleasing marine and estuarine waters for tourism, recreational swimming, fishing, and boating, as well as commercial fin fishing and shellfishing. The continued degradation of these coastal sub-embayments, as described above, will significantly reduce the recreational and commercial value and use of these important environmental resources. The increase in year round residents is illustrated in the following figure:



Habitat and water quality assessments were conducted on this embayment system based upon available water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure. The embayment system in this study displays a range of habitat quality. In general, the habitat quality is highest near the tidal inlet on Nantucket Sound and poorest in the inland-most tidal reaches. This is indicated by gradients of the various indicators. Nitrogen concentrations are high throughout with a slight decrease in the central section. All eelgrass has been lost since the original 1951 survey. The dissolved oxygen records showed slight to moderate, but significant decreases in dissolved oxygen throughout the system, accompanied by above atmospheric equilibrium levels of dissolved oxygen in Scudder Bay. Elevated levels of chlorophyll *a* (5-10 ug/L) were relatively common and followed the pattern of the oxygen depletion. The benthic infauna study showed that most of the Centerville River - East Bay basins are healthy to moderately impaired.

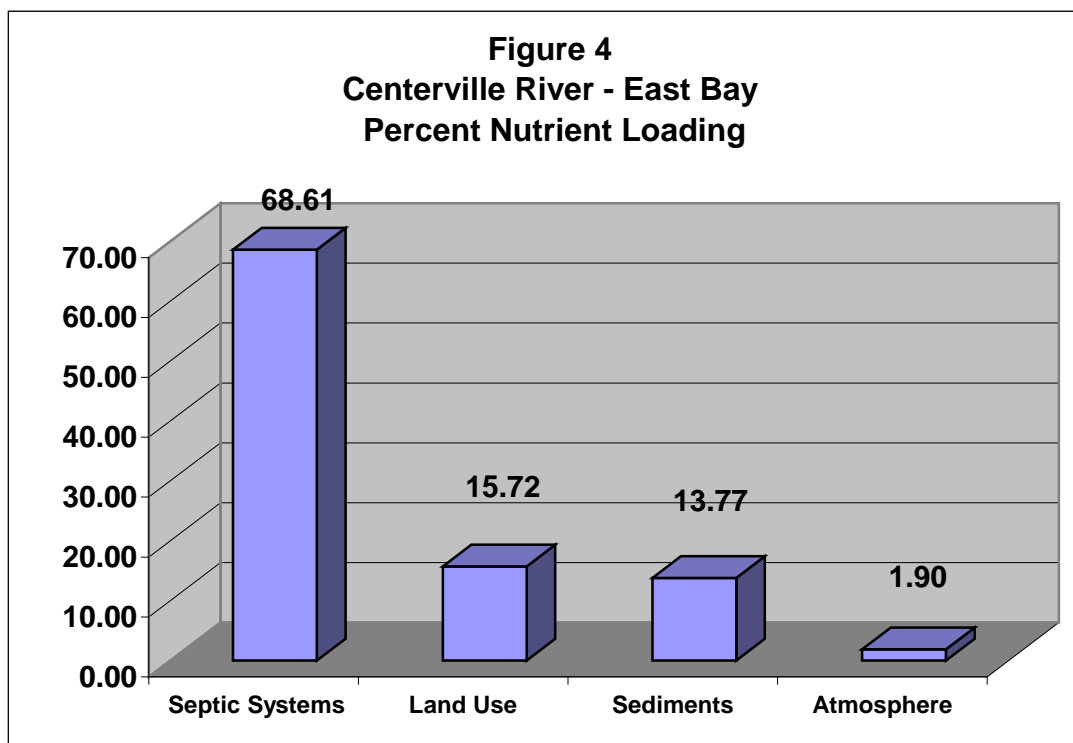
## Pollutant of Concern, Sources, and Controllability

In the coastal embayments of the Town of Barnstable, as in most marine and coastal waters, the limiting nutrient is nitrogen. Nitrogen concentrations beyond those expected naturally contribute to undesirable conditions, including the severe impacts described above, through the promotion of excessive growth of plants and algae, including nuisance vegetation.

The embayment covered in this TMDL has had extensive data collected and analyzed through the Massachusetts Estuaries Program (MEP) and with the cooperation and assistance from the Town of Barnstable, the USGS, and the Cape Cod Commission. Data collection included both water quality and hydrodynamics as described in Chapters I, IV, V, and VII of the MEP Technical Report.

These investigations revealed that loadings of nutrients, especially N, are much larger than they would be under natural conditions, and as a result the water quality has deteriorated. A principal indicator of decline in water quality is the disappearance of eelgrass from its natural habitat in this embayment. This is a result of nutrient loads causing excessive growth of algae in the water (phytoplankton) and algae growing on eelgrass (epiphyton), both of which result in the loss of eelgrass through the reduction of available light levels.

As is illustrated by Figure 4, most of the N affecting this embayment system originates from on-site subsurface wastewater disposal systems (septic systems), with a lower level coming from land use, sediments, and atmospheric deposition.



The level of “controllability” of each source, however, varies widely:

Atmospheric nitrogen cannot be adequately controlled locally – it is only through region- and nation-wide air pollution control initiatives that reductions are feasible;

Sediment nitrogen control by such measures as dredging is not feasible on a large scale. However, the concentrations of N in sediments, and thus the loadings from the sediments, will decline over time if sources in the watershed are removed, or reduced to the target levels discussed later in this document. Increased dissolved oxygen will help keep nitrogen from fluxing;

Fertilizer related nitrogen loadings can be reduced through bylaws and public education;

Stormwater sources of N can be controlled by best management practices (BMPs), bylaws and stormwater infrastructure improvements;

Septic system sources of nitrogen are the largest controllable sources. These can be controlled by a variety of case-specific methods including: sewerage and treatment at centralized or decentralized locations, upgrading/repairing failed systems, transporting and treating septage at treatment facilities with N removal technology either in or out of the watershed, or installing nitrogen-reducing on-site wastewater treatment systems.

Natural Background is the background load as if the entire watershed was still forested and contains no anthropogenic sources. It cannot be controlled locally.

Cost/benefit analyses will have to be conducted on all of the possible N loading reduction methodologies in order to select the optimal control strategies, priorities, and schedules.

## **Description of the Applicable Water Quality Standards**

Water quality standards of particular interest to the issues of cultural eutrophication are dissolved oxygen, nutrients, aesthetics, excess plant biomass, and nuisance vegetation. The Massachusetts water quality standards (314 CMR 4.0) contain numeric criteria for dissolved oxygen, but have only narrative standards that relate to the other variables, as described below:

314 CMR 4.05(5)(a) states “Aesthetics – All surface waters shall be free from pollutants in concentrations 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.”

314 CMR 4.05(5)(c) states, “Nutrients – Shall not exceed the site-specific limits necessary to control accelerated or cultural eutrophication”.

314 CMR 4.05(b) 1:

(a) Class SA

1. Dissolved Oxygen -

- a. Shall not be 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; and
- c. site-specific criteria may apply where background conditions are lower than specified levels or to the bottom stratified layer where the Department determines that designated uses are not impaired.

(b) Class SB

1. Dissolved Oxygen -

- a. Shall not be 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; and
- c. site-specific criteria may apply where background conditions are lower than specified levels or to the bottom stratified layer where the Department determines that designated uses are not impaired.

Thus, the assessment of eutrophication is based on site-specific information within a general framework that emphasizes impairment of uses and preservation of a balanced indigenous flora and fauna. This approach is recommended by the US Environmental Protection Agency in their draft Nutrient Criteria Technical Guidance Manual for Estuarine and Coastal Marine Waters (EPA-822-B-01-003, Oct 2001). The Guidance Manual notes that lakes, reservoirs, streams, and rivers may be subdivided by classes, allowing reference conditions for each class and facilitating cost-effective criteria development for nutrient management. However, individual estuarine and coastal marine waters have unique characteristics, and development of individual water body criteria is typically required.

It is this framework, coupled with an extensive outreach effort that the Department, and technical support of SMAST, that MassDEP is employing to develop nutrient TMDLs for coastal waters.

## **Methodology - Linking Water Quality and Pollutant Sources**

Extensive data collection and analyses have been described in detail in the MEP Technical Report. Those data were used by SMAST to assess the loading capacity of each sub-embayment. Physical (Chapter V), chemical, and biological (Chapters IV, VII, and VIII) data were collected and evaluated. The primary water quality objective was represented by conditions that:

- 1) restore the natural distribution of eelgrass because it provides valuable habitat for shellfish and finfish
- 2) prevent algal blooms
- 3) protect benthic communities from impairment or loss
- 4) maintain dissolved oxygen concentrations that are protective of the estuarine communities.



The details of the data collection, modeling and evaluation are presented and discussed in Chapters IV, V, VI, VII and VIII of the MEP Technical Report. The main aspects of the data evaluation and modeling approach are summarized below, taken from pages 4 through 9 of that report.

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” like 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 “what if” scenarios.

The Linked Model has been applied previously to watershed N management in over 15 embayments throughout Southeastern Massachusetts. In these applications it became clear that the model can be calibrated and validated, and has use as a management tool for evaluating watershed N management options.

The Linked Model, when properly calibrated and validated for a given embayment, becomes a N management-planning tool as described in the model overview below. 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) N sensitivity, (2) N threshold loading levels (TMDL) 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 (Figure I-3 of the MEP Technical Report). This methodology integrates a variety of field data and models, specifically:

- Monitoring - multi-year 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 Nitrogen Loading
  - watershed delineation
  - stream flow (Q) and N load
  - land-use analysis (GIS)
  - watershed N model
- Embayment TMDL - Synthesis
  - linked Watershed-Embayment Nitrogen Model
  - salinity surveys (for linked model validation)
  - rate of N recycling within embayment
  - dissolved oxygen record
  - macrophyte survey
  - infaunal survey (in complex systems)

#### ***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, includes:

- 1) selecting 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” stations;
- 2) using site-specific information and a minimum of three years of sub-embayment-specific data to select target threshold N concentrations for each sub-embayment. This is done by refining the draft threshold N 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;



- 3) running the calibrated water quality model using different watershed N loading rates, to determine the loading rate, which will achieve the target N concentration at the sentinel station. Differences between the modeled N load required to achieve the target N concentration, and the present watershed N load, represent N management goals for restoration and protection of the embayment system as a whole.

Previous sampling and data analyses, and the modeling activities described above, resulted in four major outputs that were critical to the development of the TMDL. Two outputs are related to N **concentration**:

- the present N concentrations in the sub-embayments
- site-specific target threshold N concentrations

and, two outputs are related to N **loadings**:

- the present N loads to the sub-embayments
- load reductions necessary to meet the site specific target threshold N concentrations

In summary: meeting the water quality standards by reducing the nitrogen concentration (and thus the nitrogen load) at the sentinel station, the water quality goals will be met throughout the entire system.

A brief overview of each of the outputs follows:

Nitrogen concentrations in the sub-embayments

a) Observed “present” conditions:

Table 2 presents the average concentration of N measured in this embayment from five years of data collection (during the period 2001 through 2005). ). Concentrations of N are the highest at the most upstream end of Centerville River 0.79 mg/L (Station BC-5). Nitrogen at the other stations in the embayment ranges in concentration from 0.33 to 0.66 mg/L, resulting in overall ecological habitat quality that is significantly impaired. The overall means and standard deviations of the averages are presented in Appendix A (reprinted from Table VI-1 of the accompanying Tech Report).

b) Modeled site-specific target threshold nitrogen concentrations:

A major component of TMDL development is the determination of the maximum concentrations of N (based on field data) that can occur without causing unacceptable impacts to the aquatic environment. Prior to conducting the analytical and modeling activities described above, SMAST selected appropriate nutrient-related environmental indicators and tested the qualitative and quantitative relationship between those indicators and N concentrations. The Linked Model was then used to determine site-specific threshold N concentrations by using the specific physical, chemical, and biological characteristics of each sub-embayment.

As listed in Table 2, the site-specific target (threshold) N concentration is 0.37 mg/L. The findings of the analytical and modeling investigations for this embayment system are discussed and explained below:

The threshold N level for an embayment represents the average water column concentration of N that will support the habitat quality being sought. The water column N level is ultimately controlled by the integration of the watershed N load, the N concentration in the inflowing tidal waters (boundary condition) and dilution and flushing via tidal flows. The water column N concentration is modified by the extent of sediment uptake and/or regeneration and by direct atmospheric deposition.

**Table 2. Observed present nitrogen concentrations and sentinel station threshold nitrogen target concentrations derived for the Centerville River - East Bay embayment system**

Centerville River - East Bay (Station I.D.)	Embayment Observed Nitrogen Concentration <sup>1</sup> (mg/L)	Sentinel Station Threshold Nitrogen Target Concentrations (mg/L)
Centerville River (BC-5,7,8,9)	0.43-0.75 <sup>2</sup>	0.50 <sup>3</sup>
East Bay (BC-10)	0.41	
Bumps River (BC-4)	0.48	
Scudder Bay (BC-3)	0.62	0.50 <sup>3</sup>
Sentinel Station (BC-T)	No data	0.37
Nantucket Sound (Boundary Condition)	0.33	

<sup>1</sup> calculated as the average of the separate yearly means of 2001-2005 data. Overall means and standard deviations of the average are presented in Tables A-1 Appendix A.

<sup>2</sup> listed as a range since it was sampled as several segments (see Table A-1, Appendix A).

<sup>3</sup> The threshold value of 0.50 mg/l applies to the Centerville River @ station BC-7, and Scudder Bay @station BC-3 for the protection of benthic habitat.

Threshold N levels for each of the 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, diverse benthic animal communities, and dissolved oxygen levels that would support Class SA waters. Chlorophyll *a* was also considered in the assessment.

Watershed nitrogen loads (Tables ES-1 and ES-2 from the MEP Technical Report) for Centerville River - East Bay embayment system was comprised primarily of wastewater nitrogen. Analysis of the data indicates that of the controllable load the septic systems contribute 81%, and land use contributes 19%.

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; 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 Centerville River embayment system in Barnstable were determined as follows:

#### Centerville River – East Bay Threshold Nitrogen Concentrations

Following the MEP protocol, the restoration target for the Centerville River system should reflect both recent pre-degradation habitat quality and be reasonably achievable. Based upon the assessment data (Chapter VII), the Centerville River System is presently supportive of infaunal habitat throughout its component basins. However, there is a moderate level of infaunal habitat impairment within Scudder Bay and the mid region of the Centerville River, requiring nitrogen management for restoration. The primary habitat issue within the Centerville River System relates to the loss of eelgrass from the lower estuary, specifically from the Centerville River west of the entrance to Bumps River and in East Bay. This loss of eelgrass classifies these areas as "significantly impaired", although they presently support healthy to moderately healthy infaunal communities. Further impairment to both the infaunal habitat in Scudder Bay and the eelgrass habitat in the lower estuary are supported by the variety of other indicators, which support the conclusion that these impairments are the result of nitrogen enrichment, primarily from watershed nitrogen loading.

The target nitrogen concentration (tidally averaged TN) for restoration of eelgrass at the sentinel location within the lower reach of the Centerville River (region seaward of the mouth of the Bumps River) was determined to be 0.37 mg/L N. This nitrogen level is based upon the absence of eelgrass in the Lower Centerville River at a tidally averaged TN of 0.40 mg/L N and comparison to a stable eelgrass system in a similarly configured basin, the lower Oyster River (Chatham) at 0.37 mg/L N. Note: that this level is only slightly lower than that determined by the MEP Technical Team for nearby Popponesset Bay (0.38 mg/L N). This difference relates to the much shallower water in Popponesset Bay than in the Centerville River. Water depth is important as the same phytoplankton concentration that results in shading of eelgrass in deep water, will allow sufficient light to support eelgrass in shallow water. The need for a lower threshold in deeper versus shallower water was seen in the MEP eelgrass habitat assessment for Bournes Pond, Falmouth.

The threshold nitrogen level at the sentinel station within the Centerville River System is within the range found for other complex systems such as 0.38 mg/L N for Stage Harbor, 0.38 mg/L N for Bournes Pond and nearby Popponesset Bay and 0.35 mg/L N for West Falmouth Harbor and Phinneys Harbor. The sentinel station under present loading conditions supports a tidally corrected average concentration of 0.40 mg/L N, so watershed nitrogen management will be required for restoration of the estuarine habitats within this system.

Although the nitrogen management target is restoration of eelgrass habitat (and

associated water clarity, shellfish and fisheries resources), benthic infaunal habitat quality must also be supported as a secondary condition. At present, in the regions with impaired infaunal habitat, the tidally averaged total nitrogen (TN) level under existing conditions is 0.53 mg/L N in Scudder Bay and between 0.54-0.47 mg/L N in the middle reach of the Centerville River (bridge to Bumps River). The observed moderate impairment at these sites is consistent with observations by the MEP Technical Team in other enclosed basins along Nantucket Sound (e.g. Perch Pond, Bournes Pond, Popponesset Bay) where levels <0.5 mg/L N were found to be supportive of healthy infaunal habitat and in deeper enclosed basins in Buzzards Bay (e.g. Eel Pond in Bourne) where healthy infaunal habitat had a slightly lower threshold level, 0.45 mg/L N, due to those being a "deep" depositional basin. The higher TN levels observed in the upper Centerville River salt marshes are within the nitrogen threshold to support the observed healthy infaunal habitat in this estuarine reach. To ensure that meeting the nitrogen threshold at the sentinel station (BC-T, just seaward of the mouth of the Bumps River within the Centerville River, upgradient from BC-9) results in restoration of the moderately impaired infaunal habitats in Scudder Bay and the middle reach of the Centerville River, nitrogen criteria for secondary infaunal "check" stations were developed by the MEP Technical Team. Based upon the Centerville River system showing moderate impairment at tidally averaged TN levels of 0.53 mg/L N in Scudder Bay (BC-3) and 0.54 at the inland end of the middle reach of the Centerville River (BC-7) and the results from nearby embayments to Nantucket Sound (noted above), it was concluded that an upper limit of 0.50 mg/L N tidally averaged TN would support healthy infaunal habitat in these inner regions.

It is important to note that the analysis of future nitrogen loading to the Centerville River 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 conclusion of the MEP analysis of the Centerville River estuarine system is that restoration will necessitate reduction in the present (2005) nitrogen inputs and management options to negate additional future nitrogen inputs.

#### Nitrogen loadings to the embayment

##### a) Present loading rates:

In the Centerville River - East Bay embayment system overall, the highest N loading from controllable sources is from septic systems. Nitrogen loading from the nutrient-rich sediments (referred to as benthic flux) is significant in this embayment.

As discussed previously, however, the direct control of N from sediments is not considered feasible. However, the magnitude of the benthic contribution is related to the watershed load. Therefore, reducing the incoming load should reduce the benthic flux over time. The total N loading from all sources was 156.79 kg/day across Centerville River - East Bay embayment. A further breakdown of N loading, by source, is presented in Table 3. The data on which Table 3 is based can be found in Table ES-1 of the MEP Technical Report.

**Table 3. Nitrogen loading to Centerville River - East Bay System**

Centerville River - East Bay Embayment	Present Land Use Load <sup>1</sup> (kg/day)	Present Septic System Load (kg/day)	Benthic Input <sup>2</sup> (kg/day)	Present Atmospheric Deposition (kg/day)	Total nitrogen load from all sources (kg/day)
Centerville River	12.97	57.98	8.89	1.17	81.01
East Bay	2.33	6.30	12.69	1.13	22.46
Scudder Bay	9.35	43.28	0	0.69	53.32

<sup>1</sup> composed of fertilizer, runoff, and atmospheric deposition to lakes

<sup>2</sup> negative benthic flux has been set to zero as it is not a load

As previously indicated, the present N loadings to Centerville River - East Bay embayment system must be reduced in order to restore conditions and to avoid further nutrient-related adverse environmental impacts. The critical final step in the development of the TMDL is modeling and analysis to determine the loadings required to achieve the target N concentrations.

b) Nitrogen loads necessary for meeting the site-specific target nitrogen concentrations.

Table 4 lists the present controllable watershed N loadings from Centerville River - East Bay embayment system. The last two columns indicate one scenario of the reduced loads and percentage reductions that could achieve the target concentrations in the sentinel system (see following section). It is very important to note that load reductions can be produced through reduction of any or all sources of N, potentially increasing the natural attenuation of nitrogen within the freshwater systems to the embayment, and/or modifying the tidal flushing through inlet reconfiguration (where appropriate). The load reductions presented below represent only one of a suite of potential reduction approaches that need to be evaluated by the communities involved. This presentation is to establish the general degree and spatial pattern of reduction that will be required for restoration of these N impaired embayments.

As previously noted, the loadings presented in Table 4 represent one, but not the only, loading reduction scenario that can meet the TMDL goal. Other alternatives may also achieve the desired threshold concentration as well and can be explored using the MEP modeling approach. In the scenario presented, the percentage reductions in N loadings to meet the target threshold concentrations range from 0% in East Bay and Scudder Bay to 52 % in Centerville River. Table VIII-2 of the MEP Technical Report (and rewritten as Appendix B of this document) summarizes the present loadings from on-site subsurface wastewater disposal systems and the reduced loads that would be necessary to achieve the threshold N concentrations in the Centerville River - East Bay embayment system, under the scenario modeled here. In this scenario only the on-site subsurface wastewater disposal system loads were reduced to the level of the target threshold watershed load. It should be emphasized once again that this is only one scenario that will meet the target N concentrations in the sentinel systems, which is the ultimate goal of the TMDL. There can be variations depending on the chosen sub-watershed and which controllable source is

selected for reduction. Alternate scenarios will result in different amounts of nitrogen being reduced in different sub-watersheds. For example, taking out additional nitrogen upstream will impact how much nitrogen has to be taken out downstream. The town of Barnstable should take any reasonable effort to reduce the controllable nitrogen sources.

**Table 4. Present Controllable Watershed nitrogen loading rate, calculated loading rate that is necessary to achieve target threshold nitrogen concentration, and the percent reduction of the existing load necessary to achieve the target threshold load.**

Embayments	Present controllable watershed load <sup>1</sup> (kg/day)	Target threshold watershed load <sup>2</sup> (kg/day)	Percent controllable watershed load reductions needed to achieve threshold loads
Centerville River	70.95	34.18	52%
East Bay	8.63	8.63	0%
Scudder Bay	52.63	52.63	0%

<sup>1</sup> Composed of combined land use, and septic system loadings

<sup>2</sup> Target threshold watershed load is the load from the watershed needed to meet the embayment threshold N concentrations identified in Table 2 above

## Total Maximum Daily Loads

As described in EPA guidance, a total maximum daily load (TMDL) identifies the loading capacity of a water body for a particular pollutant. EPA regulations define loading capacity as the greatest amount of loading that a water body can receive without violating water quality standards. The TMDLs are established to protect and/or restore the estuarine ecosystem, including eelgrass, the leading indicator of ecological health, thus meeting water quality goals for aquatic life support. Because there are no “numerical” water quality standards for N, the TMDLs for the Centerville River - East Bay embayment system is aimed at determining the loads that would correspond to specific N concentrations determined to be protective of the water quality and ecosystems.

The effort includes detailed analyses and mathematical modeling of land use, nutrient loads, water quality indicators, and hydrodynamic variables (including residence time), for each sub-embayment. The results of the mathematical model are correlated with estimates of impacts on water quality, including negative impacts on eelgrass (the primary indicator), as well as dissolved oxygen, chlorophyll, and benthic infauna.

The TMDL can be defined by the equation:

$$\text{TMDL} = \text{BG} + \text{WLAs} + \text{LAs} + \text{MOS}$$

Where

TMDL = loading capacity of receiving water

BG = natural background

WLAs = portion allotted to point sources

LAs = portion allotted to (cultural) non-point sources

MOS = margin of safety

## **Background Loading**

Natural background N loading estimates are presented in Table ES-1 of the MEP Technical Report. Background loading was calculated on the assumption that the entire watershed is forested, with no anthropogenic sources of N.

## **Wasteload Allocations**

Wasteload allocations identify the portion of the loading capacity allocated to existing and future point sources of wastewater. EPA interprets 40 CFR 130.2(h) to require that allocations for NPDES regulated discharges of storm water be included in the waste load component of the TMDL. On Cape Cod there are no surface water NPDES discharges discharging directly the surface waters in the Centerville Harbor embayment system and the vast majority of storm water percolates into the ground and aquifer and proceeds into the embayment systems through groundwater migration. The Linked Model accounts for storm water loadings and groundwater loading in one aggregate allocation as a non-point source – combining the assessments of waste water and storm water (including storm water that infiltrates into the soil and direct discharge pipes into water bodies) for the purpose of developing control strategies. Although the vast majority of storm water percolates into the ground, there are a few storm water pipes that discharge directly to water bodies that are subject to the requirements of the Phase II Storm Water NPDES Program. Therefore, any storm water discharges subject to the requirements of storm water Phase II NPDES permit must be treated as a waste load allocation. Since the majority of the nitrogen loading comes from septic systems, fertilizer, and storm water that infiltrates into the groundwater, the allocation of nitrogen for any storm water pipes that discharge directly to any of the embayments is insignificant as compared to the overall groundwater load. Based on land use, the Linked Model accounts for loading for storm water, but does not differentiate storm water into a load and waste load allocation. Nonetheless, based on the fact that there are few storm water discharge pipes within NPDES Phase II communities that discharge directly to embayments or waters that are connected to the embayments, the total waste load allocation for these sources is considered to be insignificant. This is based on the percent of impervious surface within 200 feet of the waterbodies and the relative load from this area compared to the overall load (Table IV-4 of the MEP Technical Report). Although most stormwater infiltrates into the ground on Cape Cod, some impervious areas within approximately 200 feet of the shoreline may discharge stormwater via pipes directly to the waterbody. For the purposes of waste load allocation it was assumed that all impervious surfaces within 200 feet of

the shoreline discharge directly to the waterbody. This calculated load is 0.5% of the total load or 3972 kg/year as compared to the overall nitrogen load of 48,277 kg/year to the embayments. Looking at individual sub-embayments this load ranged from 0.3-1.3% compared to the individual nitrogen load to each sub-embayment (see Appendix C for details). This conservative load is obviously negligible when compared to other sources.

EPA policy also requires that stormwater regulated under the NPDES program be identified and included as a wasteload allocation. As discussed below, for the purpose of this TMDL, stormwater loadings are not differentiated into point and non-point sources.

EPA and MassDEP authorized the Town of Barnstable for coverage under the NPDES Phase II General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) in 2003. The Phase II general permit requires the permittee to determine whether the approved TMDL is for a pollutant likely to be found in storm water discharges from the MS4. The MS4 is required to implement the storm water waste load allocation, BMP recommendations, or other performance requirements of a TMDL and assess whether the waste load allocation is being met through implementation of existing stormwater control measures or if additional control measures are necessary.

### **Load Allocations**

Load allocations identify the portion of loading capacity allocated to existing and future nonpoint sources. In the case of the Centerville River - East Bay embayment system, the nonpoint source loadings are primarily from the on-site subsurface wastewater disposal systems. Additional N sources include land use (runoff and fertilizers) and atmospheric deposition.

Generally, stormwater that is subject to the EPA Phase II Program would be considered a part of the wasteload allocation, rather than the load allocation. As presented in Chapter IV, V, and VI, of the MEP Technical Report, on Cape Cod the vast majority of stormwater percolates into the aquifer and enters the embayment system through groundwater. Given this, the TMDL accounts for stormwater loadings and groundwater loadings in one aggregate allocation as a non-point source, thus combining the assessments of wastewater and storm water for the purpose of developing control strategies. Ultimately, when the Phase II Program is implemented in Barnstable, new studies, and possibly further modeling, will identify what portion of the stormwater load may be controllable through the application of Best Management Practices (BMPs).

The sediment loading rates incorporated into the TMDL are lower than the existing sediment flux rates listed in Table 3 above because projected reductions of N loadings from the watershed will result in reductions of nutrient concentrations in the sediments, and therefore, over time, reductions in loadings from the sediments will occur. Benthic N flux is a function of N loading and particulate organic nitrogen (PON). Projected benthic fluxes are based upon projected PON concentrations and watershed N loads, and are calculated by multiplying the present N flux by the ratio of projected PON to present PON, using the following formulae:

Projected N flux = (present N flux) (PON projected / PON present)



When:  $PON_{\text{projected}} = (R_{\text{load}}) (D_{\text{PON}}) + PON_{\text{present offshore}}$

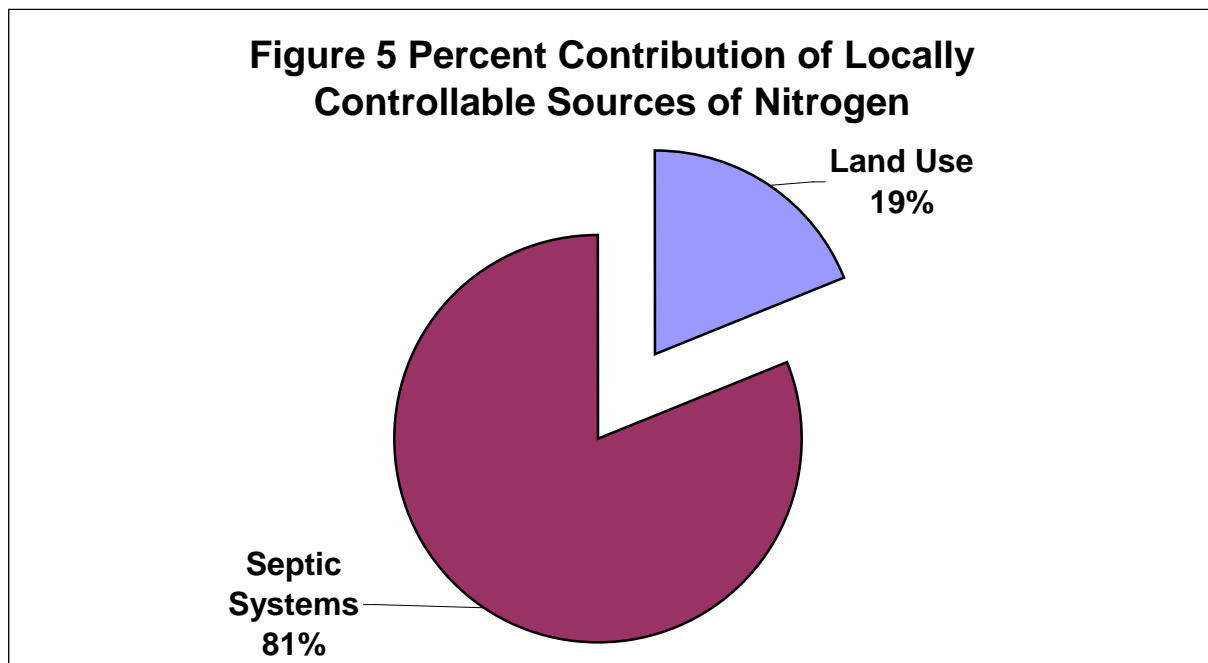
When  $R_{\text{load}} = (\text{projected N load}) / (\text{Present N load})$

And  $D_{\text{PON}}$  is the PON concentration above background determined by:

$$D_{\text{PON}} = (PON_{\text{present embayment}} - PON_{\text{present offshore}})$$

The benthic flux modeled for the Centerville River – East Bay system is reduced from existing conditions based on the load reduction and the observed PON concentrations within each sub-embayment relative to Nantucket Sound (boundary condition). The benthic flux input to each sub-embayment was reduced (toward zero) based on the reduction of N in the watershed load. The loadings from atmospheric sources incorporated into the TMDL, however, are the same rates presently occurring, because, as discussed above, local control of atmospheric loadings is not considered feasible.

Locally controllable sources of N within the watersheds are categorized as on-site subsurface wastewater disposal system wastes and land use (which includes stormwater runoff and fertilizers). Figure 5 emphasizes the fact that the overwhelming majority of locally controllable N comes from on-site subsurface wastewater disposal systems.



## Margin of Safety

Statutes and regulations require that a TMDL include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality [CWA para 303 (d)(20), 40C.G.R. para 130.7(1)]. The EPA's 1991 TMDL Guidance explains that the MOS may be implicit, i.e., incorporated into the TMDL through conservative assumptions in the analysis, or explicit, i.e., expressed in the TMDL as loadings set aside for the MOS. The MOS for the Centerville River - East Bay System TMDL is implicit, and the conservative assumptions in the analyses that account for the MOS are described below.

### 1. Use of conservative data in the linked model

The watershed N model provides conservative estimates of N loads to the embayments. Nitrogen transfer through direct groundwater discharge to estuarine waters is based upon studies indicating negligible aquifer attenuation and dilution, i.e. 100% of load enters embayment. This is a conservative estimate of loading because studies have also shown that in some areas less than 100% of the load enters the estuary. Nitrogen from the upper watershed regions, which travel through ponds or wetlands, almost always enter the embayment via stream flow, are directly measured (over 12-16 months) to determine attenuation. In these cases the land-use model has shown a slightly higher predicted N load than the measured discharges in the streams/rivers that have been assessed to date. Therefore, the watershed model as applied to the surface water watershed areas again presents a conservative estimate of N loads because the actual measured N in streams was lower than the modeled concentrations.

The hydrodynamic and water quality models have been assessed directly. In the many instances where the hydrodynamic model predictions of volumetric exchange (flushing) have also been directly measured by field measurements of instantaneous discharge, the agreement between modeled and observed values has been  $\geq 95\%$ . Field measurement of instantaneous discharge was performed using acoustic doppler current profilers (ADCP) at key locations within the embayment (with regards to the water quality model, it was possible to conduct a quantitative assessment of the model results as fitted to a baseline dataset - a least squares fit of the modeled versus observed data showed an  $R^2 > 0.95$ , indicating that the model accounted for 95% of the variation in the field data). Since the water quality model incorporates all of the outputs from the other models, this excellent fit indicates a high degree of certainty in the final result. The high level of accuracy of the model provides a high degree of confidence in the output; therefore, less of a margin of safety is required.

In the case of N attenuation by freshwater ponds, attenuation was derived from measured N concentrations, pond delineations and pond bathymetry. These attenuation factors were higher than that used in the land-use model. The reason was that the pond data were temporally limited and a more conservative value of 40% was more protective and defensible.

In the case of the nitrogen load assessed to lawn fertilization rates for residential lawns, based on an actual survey, it is likely that this represents a conservative estimate of the nitrogen load. This

too makes a more conservative margin of safety. The nitrogen loading calculations are based on a wastewater engineering assumption that 90% of water used is converted to wastewater. Actual water use and conversion studies in the area have shown that this conversion rate is conservative adding to the margin of safety.

The nitrogen loading calculations for homes, which do not have metered water use, are based on a conservative estimate of water use compared to actual water use in the metered sections of the watershed. This adds to the margin of safety.

Similarly, the water column N validation dataset was also conservative. The model is validated to measured water column N. However, the model predicts average summer N concentrations. The very high or low measurements are marked as outliers. The effect is to make the N threshold more accurate and scientifically defensible. If a single measurement two times higher than the next highest data point in the series, raises the average 0.05 mg/L N, this would allow for a higher “acceptable” load to the embayment. Marking the very high outlier is a way of preventing a single and rare bloom event from changing the N threshold for a system. This effectively strengthens the data set so that a higher margin of safety is not required.

## 2. Conservative sentinel station/target threshold nitrogen concentrations

Conservatism was used in the selection of the sentinel stations and target threshold N concentrations. Sites were chosen that had stable eelgrass or benthic animal (infaunal) communities, and not those just starting to show impairment, which would have slightly higher N concentrations. Meeting the target threshold N concentrations at the sentinel station will result in reductions of N concentrations in the rest of the system.

## 3 Conservative approach

The target loads were based on tidally-averaged N concentrations on the outgoing tide, which is the worst case condition because that is when the N concentrations are the highest. The N concentrations will be lower on the flood tides; therefore, this approach is conservative.

In addition to the margin of safety within the context of setting the N threshold levels, described above, a programmatic margin of safety also derives from continued monitoring of these subembayments to support adaptive management. This continuous monitoring effort provides the ongoing data to evaluate the improvements that occur over the multi-year implementation of the N management plan. This will allow refinements to the plan to ensure that the desired level of restoration is achieved.

## **Seasonal Variation**

Since the TMDL for the waterbody segment is based on the most critical time period, i.e. the summer growing season, the TMDL is protective for all seasons. The daily loads can be converted to annual loads by multiplying by 365 (the number of days in a year). Nutrient loads to the embayment are based on annual loads for two reasons. The first is that primary production in coastal waters can peak in both the late winter-early spring and in the late summer-early fall periods. Second, as a practical matter, the types of controls necessary to control the N load, the nutrient of primary concern, by their very nature do not lend themselves to intra-annual

manipulation since the majority of the N is from non-point sources. Thus, the annual loads make sense, since it is difficult to control non-point sources of nitrogen on a seasonal basis and nitrogen sources can take considerable time to migrate to impacted waters.

### **TMDL Values for Centerville River - East Bay embayment system**

As outlined above, the total maximum daily loadings of N that would provide for the restoration and protection of the embayment were calculated by considering all sources of N grouped by point sources and non-point sources. A more meaningful way of presenting the loadings data, from an implementation perspective, is presented in Table 5. In this table the N loadings from the atmosphere and nutrient-rich sediments are listed separately from the target watershed threshold loads, which are composed of locally controllable N from the on-site subsurface wastewater disposal systems, stormwater runoff, and fertilizer sources. In the case of the Centerville River - East Bay embayment system the TMDL was calculated by projecting reductions in locally controllable on-site subsurface wastewater disposal systems. Once again the goal of this TMDL is to achieve the identified N threshold concentration at the identified sentinel station. 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. These waterbody segment TMDLs are also presented in Appendix D.

**Table 5. The Total Maximum Daily Load (TMDL) for Centerville River - East Bay embayment system, represented as the sum of the calculated target threshold load (from controllable watershed sources), atmospheric deposition, and benthic input.**

Sub-embayment	Target Threshold Watershed Load <sup>1</sup> (kg/day)	Atmospheric Deposition (kg/day)	Benthic Input (kg/day)	TMDL <sup>2</sup> (kg/day)
Centerville River	34.18	1.17	7.78	43
East Bay	8.63	1.13	12.69	22
Scudder Bay	52.63	0.69	0	53

<sup>1</sup> Target threshold watershed load is the load from the watershed needed to meet the embayment threshold concentrations identified in Table 2

<sup>2</sup> Sum of target threshold watershed load, atmospheric deposition load, and the benthic input load.

Two waterbody segments, East Bay and Scudder Bay, were not found to be impaired for nitrogen, but it was determined that a “pollution prevention” TMDL for nitrogen was needed since these waterbody segments are linked to the larger embayment system and any future impairment of these two segments could further contribute to impairment of the segments at issue in this TMDL (Appendix D). “Pollution prevention” TMDLs on these two waterbody segments will encourage the maintenance and protection of existing water quality and help prevent further degradation to

waterbodies that are downstream or linked. These pollution prevention TMDLs will serve as a guide to help ensure that these waterbodies do not become impaired for nitrogen.

## **Implementation Plans**

The critical element of this TMDL process is achieving the sentinel station specific N concentrations presented in Table 2 above, that are necessary for the restoration and protection of water quality and eelgrass habitat within the Centerville River - East Bay embayment system. In order to achieve those target concentrations, N loading rates must be reduced throughout these three embayments. Table 5, above, lists the target watershed threshold load. If this threshold loads is achieved, this embayment will be protected.

As previously noted, this loading reduction scenario is not the only way to achieve the target N concentrations. Barnstable is free to explore other loading reduction scenarios through additional modeling as part of the Comprehensive Wastewater Management Plan (CWMP). It must be demonstrated, however, that any alternative implementation strategies will be protective of Centerville River - East Bay, and that none of the embayment will be negatively impacted. To this end, additional linked model runs can be performed by the MEP at a nominal cost to assist the planning efforts of the Town in achieving target N loads that will result in the desired threshold concentrations.

The CWMP should include a schedule of the selected strategies and estimated timelines for achieving those targets. However, the MassDEP realizes that an adaptive management approach may be used to observe implementation results over time and allow for adjustments based on those results.

Because the vast majority of controllable N load is from individual on-site subsurface wastewater disposal systems for private residences, the CWMP should assess the most cost-effective options for achieving the target N watershed loads, including but not limited to, sewerage and treatment for N control of sewage and septage at either centralized or decentralized locations, and denitrifying systems for all private residences.

Barnstable is urged to meet the target threshold N concentrations by reducing N loadings from any and all sources, through whatever means are available and practical, including reductions in stormwater runoff and/or fertilizer use within the watershed through the establishment of local by-laws and/or the implementation of stormwater BMPs, in addition to reductions in on-site subsurface wastewater disposal system loadings.

MassDEP's MEP Implementation Guidance report (<http://www.mass.gov/dep/water/resources/restore.htm>) provides N loading reduction strategies that are available to Barnstable and that could be incorporated into the implementation plans. The following topics related to N reduction are discussed in the Guidance:

- 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

\* The Town of Barnstable is one of the 237 communities in Massachusetts covered by the Phase II stormwater program requirements.

### **Monitoring Plan for TMDL Developed Under the Phased Approach**

MassDEP is of the opinion that there are two forms of monitoring that are useful to determine progress towards achieving compliance with the TMDL. They include 1) tracking implementation progress as approved in the Town CWMP plan and 2) monitoring ambient water quality conditions at the sentinel stations identified in the MEP Technical Report.

The CWMP will evaluate various options to achieve the goals set out in the TMDL and Technical Report. It will also make a final recommendation based on existing or additional modeling runs, set out required activities, and identify a schedule to achieve the most cost effective solution that will result in compliance with the TMDL. Once approved by the Department tracking progress on the agreed upon plan will, in effect, also be tracking progress towards water quality improvements in conformance with the TMDL.

Relative to water quality, MassDEP believes that an ambient monitoring program, much reduced from the data collection activities needed to properly assess conditions and to populate the model, will be important to determine actual compliance with water quality standards. Although the TMDL load values are not fixed, the target threshold nitrogen concentrations at the sentinel stations are fixed. In addition, there are target threshold N concentrations that are provided for many other non-sentinel locations in subembayments to protect nearshore benthic habitat. These are the water quality targets, and a monitoring program should encompass these stations at a minimum. Through discussions amongst the MEP it is generally agreed that existing monitoring programs, which were designed to thoroughly assess conditions and populate water quality models, can be substantially reduced for compliance monitoring purposes. Although more specific details need to be developed on a case by case basis MassDEP's current thinking is that about half the current effort (using the same data collection procedures) would be sufficient to

monitor compliance over time and to observe trends in water quality changes. In addition, the benthic habitat and communities would require periodic monitoring on a frequency of about every 3-5 years. Finally, in addition to the above, existing monitoring conducted by MassDEP for eelgrass should continue into the future to observe any changes that may occur to eelgrass populations as a result of restoration efforts.

The MEP will continue working with the Towns to develop and refine monitoring plans that remain consistent with the goals of the TMDL. It must be recognized however that development and implementation of a monitoring plan will take some time, but it is more important at this point to focus efforts on reducing existing watershed loads to achieve water quality goals.

## **Reasonable Assurances**

MassDEP possesses the statutory and regulatory authority, under the water quality standards and/or the State Clean Water Act (CWA), to implement and enforce the provisions of the TMDL, including requirements for N loading reductions from on-site subsurface wastewater disposal systems. However, because most non-point source controls are voluntary, reasonable assurance is based on the commitment of the locality involved. Barnstable has demonstrated this commitment through the comprehensive wastewater planning that they initiated well before the generation of the TMDL. The Town expects to use the information in this TMDL to generate support from their citizens to take the necessary steps to remedy existing problems related to N loading from on-site subsurface wastewater disposal systems, stormwater, and runoff (including fertilizers), and to prevent any future degradation of these valuable resources. Moreover, reasonable assurances that the TMDL will be implemented include enforcement of regulations; availability of financial incentives; and local, state, and federal programs for pollution control. Storm water NPDES permit coverage will address discharges from municipally owned storm water drainage systems. Enforcement of regulations controlling non-point discharges include local implementation of the Commonwealth's Wetlands Protection Act and Rivers Protection Act; Title 5 regulations for on-site subsurface wastewater disposal systems, and other local regulations such as the Town of Rehoboth's stable regulations. Financial incentives include federal funds available under Sections 319, 604 and 104(b) programs of the CWA, which are provided as part of the Performance Partnership Agreement between MassDEP and EPA. Other potential funds and assistance are available through Massachusetts' Department of Agriculture's Enhancement Program and the United States Department of Agriculture's Natural Resources Conservation Services. Additional financial incentives include income tax credits for Title 5 upgrades and low interest loans for Title 5 on-site subsurface wastewater disposal system upgrades available through municipalities participating in this portion of the state revolving fund program.

As the town implements this TMDL, the TMDL values (kg/day of nitrogen) will not be used by MassDEP as an enforcement tool. There will be slight variations in these values depending on the scenario the towns use to implement it. They are also modeled values and thus would be very awkward and difficult to use as an enforcement tool. There could also be slight variations between the actual nitrogen concentration at the sentinel stations and the site specific target threshold nitrogen concentration at the sentinel stations as the nitrogen load is reduced and the waterbodies begin to approach the water quality standards (Description of the Applicable Water

Quality Standards section). It will be these latter two standards, the nitrogen concentration at the sentinel station and more importantly, the applicable water quality standards that will be used as the measure of full implementation and compliance with these water quality standards.



**Appendix A: Summarizes the nitrogen concentrations for Centerville River - East Bay embayment system (from Chapter VI of the accompanying MEP Technical Report)**

Table VI-1. Pond-Watcher measured data, and modeled Nitrogen concentrations for the Centerville River System used in the model calibration plots of Figure VI-2. All concentrations are given in mg/L N. "Data mean" values are calculated as the average of the separate yearly means.							
Sub-Embayment	Scudder Bay	Bumps River	Centerville River	Centerville River	Centerville River	Centerville River	East Bay
Monitoring station	BC-3	BC-4	BC-5	BC-7	BC-8	BC-9	BC-10
2001 mean	0.593	0.325	0.697	0.484	0.423	0.332	0.330
2002 mean	0.628	0.505	0.759	0.618	0.513	0.460	0.466
2003 mean	0.661	0.542	0.793	0.589	0.588	0.433	0.413
2004 mean	0.569	0.485	0.710	0.536	0.552	0.453	0.390
2005 mean	0.610	0.423	0.720	0.467	0.474	0.399	0.382
mean	0.619	0.481	0.745	0.551	0.526	0.430	0.408
s.d. all data	0.105	0.113	0.147	0.117	0.125	0.112	0.086
N	28	28	29	29	57	55	57
model min	0.386	0.333	0.457	0.385	0.335	0.316	0.310
model max	0.695	0.616	0.749	0.670	0.584	0.514	0.442
model average	0.524	0.451	0.609	0.526	0.454	0.389	0.349

**Appendix B: Summarizes the present septic system loads, and the loading reductions that would be necessary to achieve the TMDL by reducing septic system loads, ignoring all other sources.**

Table VIII-2. Comparison of sub-embayment watershed <i>septic loads</i> (attenuated) used for modeling of present and threshold loading scenarios of the Centerville River estuary system. These loads do not include direct atmospheric deposition (onto the sub-embayment surface), benthic flux, runoff, or fertilizer loading terms.			
sub-embayment	present septic load (kg/day)	threshold septic load (kg/day)	threshold septic load % change
Centerville River East	45.929	9.184	-80.0%
Scudder Bay	11.619	11.619	+0.0%
Centerville River West	7.704	7.704	+0.0%
East Bay	6.301	6.301	+0.0%
Surface Water Sources			
Pine Street Stream	2.512	2.512	+0.0%
Lake Elizabeth Stream	1.836	1.836	+0.0%
Bumps River	14.321	14.321	+0.0%
Skunknett River	17.337	17.337	+0.0%

## Appendix C

The Centerville River - East Bay embayment system estimated wasteload allocation (WLA) from runoff of all impervious areas within 200 feet of waterbodies.

Subwatershed Name	Impervious Subwatershed buffer areas <sup>1</sup>		Total Subwatershed Impervious areas		Total Impervious Subwatershed load	Total Subwatershed load	Impervious Subwatershed buffer area WLA	
	Acres	%	Acres	%	Kg/year	Kg/year	Kg/year <sup>2</sup>	% <sup>3</sup>
Centerville River East	13.7	10.7	351.8	17.0	2006	22466	78.1	0.3
Centerville River West	9.1	9.4	36.3	10.1	180	3454	45.1	1.3
Scudder Bay	23.6	7.6	381.4	13.3	1577	19208	97.6	0.5
East Bay	5.2	9.1	41.5	12.8	210	3149	26.3	0.8
Total	51.6	8.7	811.0	14.4	3972	48277	252.7	0.5

<sup>1</sup>The entire impervious area within a 200 foot buffer zone around all waterbodies as calculated from GIS. Due to the soils and geology of Cape Cod it is unlikely that runoff would be channeled as a point source directly to a waterbody from areas more than 200 feet away. Some impervious areas within approximately 200 feet of the shoreline may discharge stormwater via pipes directly to the waterbody. For the purposes of the wasteload allocation (WLA) it was assumed that all impervious surfaces within 200 feet of the shoreline discharge directly to the waterbody.

<sup>2</sup>The impervious subwatershed buffer area (acres) divided by total subwatershed impervious area (acres) then multiplied by total impervious subwatershed load (kg/year).

<sup>3</sup>The impervious subwatershed buffer area WLA (kg/yr) divided by the total subwatershed load (kg/yr) multiplied by 100.

## Appendix D

### 3 Total Nitrogen TMDL, 1 Pollution Prevention TMDL

Sub-Embayment	Segment ID	Description	TMDL (kg/day)
Centerville River	MA96-04_2006	Previously determined to be impaired for pathogens by MassDEP. Determined to be impaired for nutrients during the development of this TMDL.	43
East Bay		Restorative TMDL (impaired by total nitrogen) for Eel grass	22
Scudder Bay		Restorative TMDL (impaired by total nitrogen, but never supported eel grass) for Benthic Fauna Habitat. Secondary nitrogen threshold limit applies for TMDL restoration.	53
Bumps River	MA96-02_2006	Previously determined to be impaired for pathogens by MassDEP. Not impaired for total nitrogen but embayments are linked (Pollution Prevention TMDL).	