# Nantucket Harbor Embayment System
# Total Maximum Daily Loads
# For Total Nitrogen


(Report # 97-TMDL-2 Control #249.0)

**COMMONWEALTH OF MASSACHUSETTS**
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January 28, 2009

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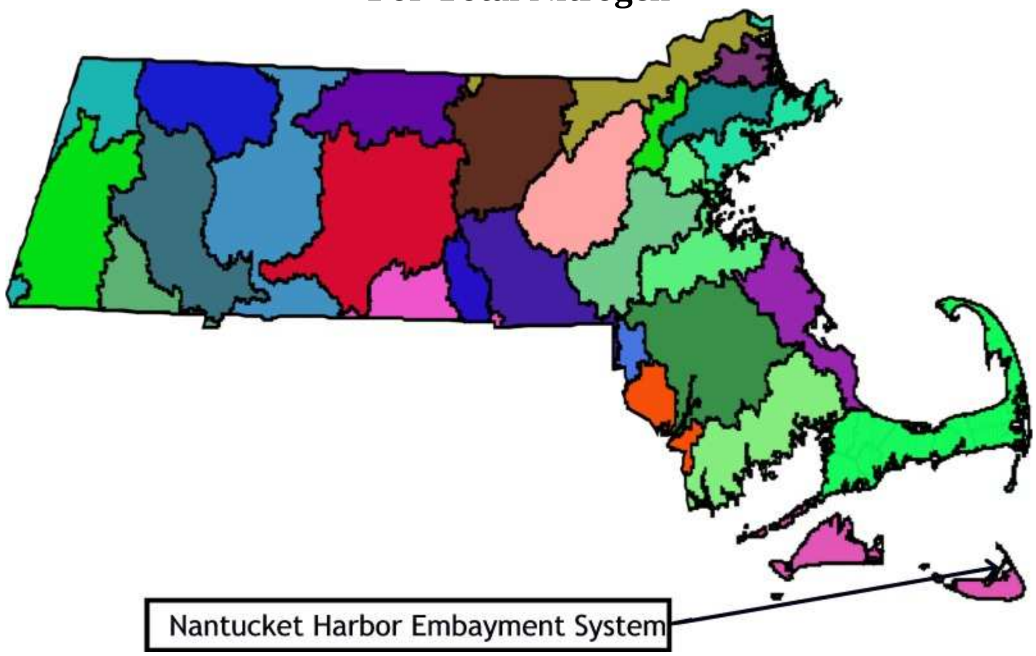



**Key Feature:** Total Nitrogen TMDL for Nantucket
**Location:** EPA Region 1
**Land Type:** New England Coastal
**303d Listing:** The water body segments impaired and on the Category 5 list includes Nantucket Harbor and Polpis Harbor.
**Data Sources:** University of Massachusetts – Dartmouth/School for Marine Science and Technology; US Geological Survey; Applied Coastal Research and Engineering, Inc.; Cape Cod Commission, Town of Nantucket.
**Data Mechanism:** Massachusetts Surface Water Quality Standards, Ambient Data, and Linked Watershed Model
**Monitoring Plan:** Town of Nantucket 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) from a variety of sources has led to decreases in the environmental quality of coastal rivers, ponds, and harbors in many communities in southeastern Massachusetts. In the coastal waters of Massachusetts the problems 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 Nantucket, 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 loss of benthic macroinvertebrates throughout most of the embayments. As a result of these environmental impacts, commercial and recreational uses of Nantucket's coastal waters could be greatly reduced.

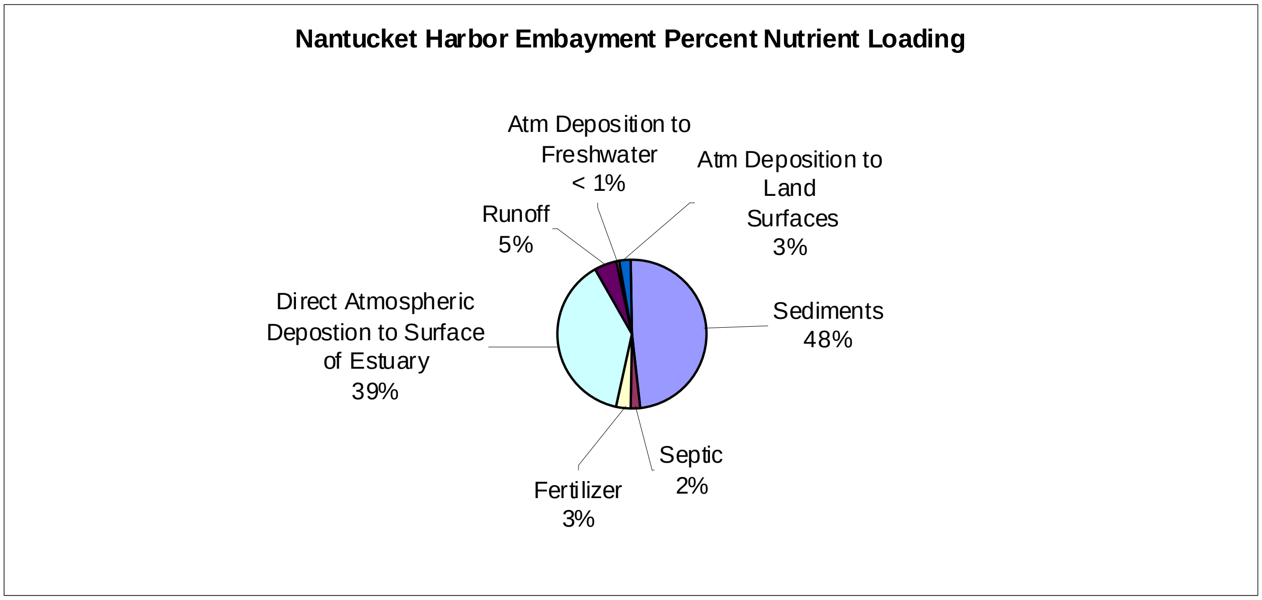
### Sources of Nitrogen

The primary sources of N loads into Nantucket Harbor are from the nutrient-rich estuarine sediments and atmospheric deposition directly onto the surface of the estuary.

The sources of N from the watershed include:

- Septic systems
- Runoff
- Fertilizers
- Natural background

The percent contribution from each source is presented in the following figure:




## Target Threshold Nitrogen Concentrations and Loadings

The N loadings (the quantity of nitrogen) to this embayment system, from all sources, ranges from 24.09 kg/day at Head of the Harbor, to 66.15 kg/day at Town Basin, with an overall nitrogen load of 149.51 kg/day to the Nantucket Harbor System from all sources. The amount of nitrogen entering the system from the surrounding watersheds (runoff, fertilizers, septic systems, and atmospheric deposition to natural surfaces) is 19.72 kg/day. The N concentrations in the harbor system range from 0.30 to 0.41 mg/L (milligrams per liter of nitrogen).

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 concentrations of 0.35 mg/L in Head of the Harbor and a N concentration of 0.36 mg/L in Polpis Harbor will allow the restoration of the habitat. 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 23 to 64 kg/day. This document presents the TMDLs for each impaired water body segment and provides guidance to the town on possible ways to reduce the nitrogen loadings to the extent possible.

## Implementation

The primary goal of implementation will be lowering the concentrations of N by reducing the loadings from on-site subsurface wastewater disposal (septic) systems, runoff, and fertilizers. Multiple strategies, proposed by Nantucket to reduce these N loadings, include sewering, storm water controls, and increased fertilizer management. These and other control methodologies are outlined in the "MEP Embayment Restoration Guidance for Implementation Strategies", that is available on the MassDEP website at http://www.mass.gov/dep/water/resources/coastalr.htm#guidance. Nantucket is determining the appropriateness of specific alternatives depending on local conditions, on a case-by-case basis, using an adaptive management approach.

Finally, growth within the community of Nantucket 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 Town 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 Nantucket Harbor Embayment 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 Nantucket Harbor Embayment System are based primarily on data collected, compiled, and analyzed by University of Massachusetts Dartmouth's School for Marine Science and Technology (SMAST), Town of Nantucket (Marine Department), and others, as part of the Massachusetts Estuaries Project (MEP). The data were collected over a study period from1988 through 1990 and from 1992 through 2005. This study period will be referred to as the "Present Conditions" in the TMDL since it is 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 Town 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 assessments of water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure that were 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 Town of Nantucket.

## Description of Water Bodies and Priority Ranking

The Nantucket Harbor Embayment System in Nantucket Massachusetts, connects to Nantucket Sound, and consists of several sub-embayments of varying size and hydraulic complexity, some of which are characterized by limited rates of flushing, shallow depths and heavily developed watersheds (see Figure 1 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 Nantucket Harbor Embayment System could be at risk of further eutrophication if nutrient loads are allowed to increase. Waterbody segments within this system are listed as waters requiring TMDLs (Category 5) in the MA 2008 Integrated List of Waters, as summarized in Table 1A.

A complete description of this embayment system is presented in Chapters I and IV of the MEP

**TABLE 1A: The Nantucket Harbor Embayment System Water Body Segments in Category 5 of the Proposed Massachusetts 2008 Integrated List**

| Name | Water body Segment | Description | Size | Pollutant Listed |
|---|---|---|---|---|
| Nantucket Harbor | MA97-01_2008 | Waters south and east of an imaginary line drawn from Jetties Beach to Coatue Point (excluding Polpis Harbor and Coskata Pond), Nantucket. | 7.2 sq mi | -Nutrients<br>-Pathogens<br>-Noxious aquatic plants |
| Polpis Harbor | MA97-26_2008 | Polpis Harbor and all adjacent coves, to an imaginary line drawn from Quaise Point to the opposite shore, Nantucket. | 0.30 sq mi | -Nutrients<br>-Other habitat alterations<br>-Pathogens |

Technical Report. A majority of the information on this embayment system is drawn from this report. Chapter VI and VII of the MEP Technical Report provide assessment data which show that the Nantucket Harbor Embayment System is impaired for excess nutrients, loss of eelgrass, low dissolved oxygen levels, elevated chlorophyll *a* levels, and benthic fauna habitat degradation.

**FIGURE 1: Overview of the Nantucket Harbor Embayment System**


The embayment system addressed by this document is determined to be a high priority based on 3 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, where possible, and preserve the embayment, and (3) the extent of impairment in parts of the embayment. In particular, this embayment is at risk of degradation if N loads entering through groundwater and surface water, from any increased development, are not controlled. The major indicators of nutrient-related habitat conditions are summarized and tabulated in Table 1B.

**TABLE 1B: General Summary of Conditions Related to the Major Indicators of Habitat Impairment Observed in the Nantucket Harbor Embayment System**

| Nantucket Harbor Embayment System | Eelgrass Loss[1] | Dissolved Oxygen Depletion | Chlorophyll *a*[2] | Macro-algae | Benthic Fauna[3] |
|---|---|---|---|---|---|
| Head of Harbor | Gradual decline in the distribution of historical eelgrass beds MI | Deep basins = generally >5 mg/L Shallow areas = generally >6 mg/L H-MI | Based on limited grab sample data H | -- [4] | Shallow areas = moderate-high numbers of individuals and species Deep region of basin = diminished numbers of individuals and species H-MI |
| Quaise | H | Deep basins = generally >5 mg/L Shallow areas = generally >6 mg/L H-MI | Based on limited grab sample data H | -- [4] | Shallow areas = moderate-high numbers of individuals and species Deep region of basin = diminished numbers of individuals and species H-MI |
| Town Basin | H | Shallow areas = generally >6 mg/L H | Based on limited grab sample data H | -- [4] | Generally high diversity and high numbers of individuals and species H |
| Polpis Harbor | Historical eelgrass beds lost in the East Basin SI | Periodic decreases to 4.5-6 mg/L, generally >6 mg/L H-MI | Based on limited grab sample data H | -- [4] | Moderate numbers of species and individuals, but high diversity and evenness H-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

[4] Very sparse or absence of drift algae

H – Healthy habitat conditions *
MI – Moderately Impaired – slight to reasonable change from normal conditions*
SI – Significantly Impaired- considerably and appreciably changed from normal conditions*
* - 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#reports

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.

## Problem Assessment

The watershed of Nantucket Harbor Embayment has had rapid and extensive development of single-family homes and the conversion of seasonal homes 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 runoff and fertilizers, and to a lesser extent, from on-site wastewater treatment systems from these developed areas.

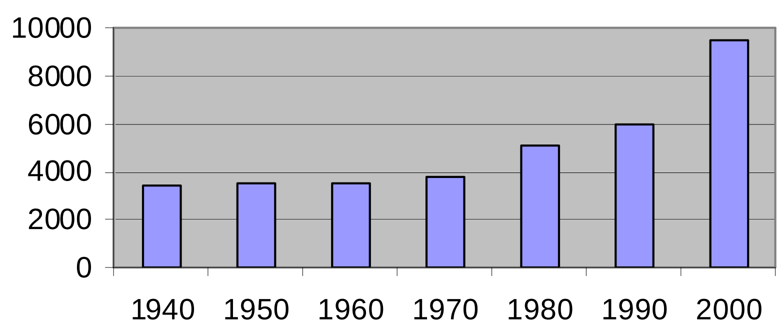
The population of Nantucket has increased markedly since 1950. In the period from 1950 to 2000 the number of year round residents has almost quadrupled. In addition, summertime residents and visitors swell the population of both the Cape and the Islands by about 300% according to the Cape Cod Commission http://www.capecodcommission.org/data/trends98.htm#population .

Prior to the 1950's there were few homes in Nantucket and most were seasonal. During these times there were no problems with water quality and eelgrass beds were plentiful. Various levels of decline in water and habitat quality in parts of Nantucket correlate with its growth in population during these times. Habitat and water quality assessments of this embayment system are based upon seven years of water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure. Observations indicate healthy or only slightly impaired conditions relative to eelgrass, dissolved oxygen, macro-algae, and benthic fauna. The only exception to this is the significant loss of eelgrass in Polpis Harbor. Increases in N loading in the future could lead to the loss of remaining eelgrass beds, 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 Nantucket, 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 Figure 2.

FIGURE 2: Nantucket Resident Population



Habitat and water quality assessments were conducted on this embayment system based upon approximately seven years of 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 highest at the more upstream sections (Head of Harbor and Polpis Harbor) and lowest near the tidal inlet to Nantucket Sound. Approximately 38% of the eelgrass beds have been lost since the original 1951 survey. The dissolved oxygen records showed mostly slight to moderate decreases with the lowest occurring in the inland-most tidal reaches. Overall the levels of chlorophyll indicated a healthy aquatic system however slightly elevated levels of chlorophyll were periodically observed and generally followed the pattern of the oxygen depletion. The benthic infauna study showed that most of the Nantucket Harbor Embayment basins are healthy to moderately impaired.

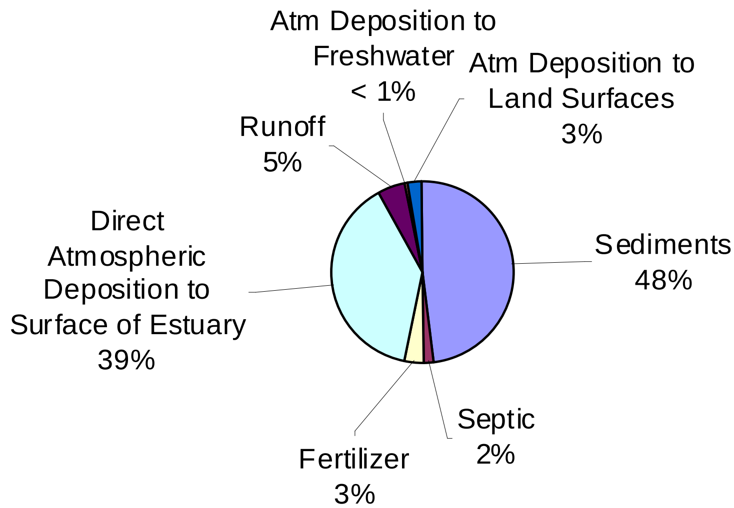
## Pollutant of Concern, Sources, and Controllability

In the coastal embayments of the Town of Nantucket, as in most marine and coastal waters, the limiting nutrient is nitrogen. Nitrogen concentrations that are higher than those occurring naturally contribute to undesirable conditions, including the impacts described above, through the promotion of excessive growth of plants and algae, including nuisance vegetation.

The embayments covered in this TMDL have had extensive data collected and analyzed through the Massachusetts Estuaries Program (MEP) and with the cooperation and assistance from the Town of Nantucket (Marine Department), the USGS, and Woods Hole Oceanographic Institute. Data collection included both water quality and hydrodynamics as described in Chapters I, IV, V, and VII of the MEP Technical Report.

As is illustrated by Figure 3, most of the N affecting this embayment system originates from the sediments and atmospheric deposition with a smaller amount coming from runoff, fertilizer, and on-site wastewater disposal systems (septic systems).

**FIGURE 3: Nantucket Harbor Embayment Percent Nutrient Loading**




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;

Storm Water/Runoff - sources of N can be controlled by best management practices (BMPs), bylaws and stormwater infrastructure improvements;

Septic system sources of nitrogen – These can be controlled by a variety of case-specific methods including: sewering and treatment at centralized or decentralized locations, 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.

Atmospheric deposition to natural surfaces (forests, fields, etc.) and lakes in the watershed – atmospheric deposition (loadings) to these areas cannot adequately be controlled locally, however the nitrogen from these sources might be subjected to enhanced natural attenuation as it moves towards the estuary.

Natural Background - the background load that contains no anthropogenic sources. It is accounted for in this study but is not quantified or presented as a separate component.

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

The waters of the Nantucket Harbor system are classified as SA. 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 or combinations that settle to form objectionable deposits; float as debris, scum, or other matter to form nuisances; produce objectionable odor, color, taste, or turbidity; or produce undesirable or nuisance species of aquatic life."

314 CMR 4.05(5)(c) states, "Nutrients. Unless naturally occurring, all surface waters shall be free from nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and shall not exceed the site specific criteria developed in a TMDL or as otherwise established…"

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.

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 tend to 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, with the technical support of SMAST, 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 3 through 7 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 2-dimensional or 3-dimensional 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-10 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 3 years of sub-embayment-specific data to select target threshold N concentrations for each sub-embayment. This is done by refining the draft target threshold N concentrations that were developed as the initial step of the MEP process. The target threshold N 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 threshold N concentration at the sentinel station. Differences between the modeled N load required to achieve the target threshold 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(s), the water quality goals will be met throughout the entire system.

A brief overview of each of the outputs follows:

<u>Nitrogen concentrations in the sub-embayments</u>

a) Observed "present" conditions:

Table 2 presents the average concentration of N measured in this embayment from seven years of data collection (during the period 1988 through 1990 and from 1992 through 2005). Concentrations of N are the highest (0.41 mg/L) at the most upstream end of Nantucket Harbor Embayment (which appears to be transitioning to a more degraded state), and in Polpis Harbor (0.36 to 0.39 mg/L) which is significantly impaired due to the loss of eelgrass. Nitrogen at the other stations in the embayment ranges in concentration from 0.30 to 0.34 mg/L, resulting in overall ecological habitat quality that is generally healthy to moderately 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 0.35 mg/L in the Head of Harbor basin and 0.36 mg/L in Polpis Harbor (to be assessed at the sentinel stations at 41°19'27"N, 70° 1'28"W and 41°18'15"N, 70° 0'52"W, respectively, and shown on the map in Appendix A) . The findings of the analytical and modeling investigations for this embayment system are discussed and explained below.

The target 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 Target Threshold Nitrogen Concentrations Derived for the Nantucket Harbor Embayment System**

| Nantucket Harbor Embayment | Embayment Observed Nitrogen Concentration [1] (mg/L) | Sentinel Station Target Threshold Nitrogen Concentrations (mg/L) |
|---|---|---|
| Head of Harbor | 0.34-0.41[2] | 0.35 |
| Quaise Basin | 0.34 | |
| Town Basin | 0.30-0.34[2] | |
| Polpis Harbor | 0.36-0.39[2] | 0.36 |
| Nantucket Sound (Boundary Condition) | 0.24 | |

[1] calculated as the average of the separate yearly means of 1988-1999 & 1992-2005 data. Overall means and standard deviations of the average are presented in Appendix A

[2] listed as a range since it was sampled as several segments (see Appendix A)

Threshold N levels for were developed to restore Polpis Harbor, and to some extent Head of Harbor, and to protect (prevent future degradation) the remainder of the harbor by maintaining 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.

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 concentrations for the Nantucket Harbor embayment system in Nantucket were determined as follows:

The restoration target for the Nantucket Harbor embayment system should reflect both recent pre-degradation habitat quality and be reasonably achievable. Determination of the critical nitrogen threshold for maintaining high quality habitat within the Nantucket Harbor embayment system is based primarily upon the nutrient and oxygen levels, temporal trends in eelgrass distribution and current benthic community indicators. This system is presently supportive of infaunal habitat throughout its main basins, but is clearly impaired by nitrogen enrichment within the Head of the Harbor basin and in the eastern basin of Polpis Harbor, based upon eelgrass losses. Given the documented importance of eelgrass habitat to these basins and the demonstrable loss of eelgrass that were supported, eelgrass restoration in these basins was set as the primary nitrogen management goal for the overall system. Due to the semi-isolated nature of Polpis Harbor from Nantucket Harbor, it is necessary to establish 2 sentinel stations for eelgrass, one in the Head of the Harbor and one in the east basin of Polpis Harbor (e.g. where eelgrass had been observed in 1951-1989).

It is important to note that the nitrogen levels throughout the Nantucket Harbor embayment system remain relatively low, consistent with the oxygen conditions, lack of macro-algae and chlorophyll a levels. However, the water depth of the Harbor and possibly vertical and horizontal mixing rates, appear to have resulted in a decline in eelgrass bed coverage from the deeper areas and more enclosed basin areas. Eelgrass was only recently lost from the east basin of Polpis Harbor - it is presently absent at a tidally averaged total nitrogen concentration of 0.36 mg/L. Loss at this nitrogen level is consistent with observed losses in West Falmouth Harbor above 0.35 mg/L N, however, given the shallower depth of Polpis Harbor, it is likely that it is just slightly above its target threshold N concentration at present. Similarly, tidally averaged levels in the lower reach of Head of the Harbor (0.34-0.35) and mid and upper reach (0.39 mg/L N) Also suggest that the recent bed losses are from a recent exceedance of the supportive target threshold N concentration. Given all of the factors discussed above and the similarity of Head of the Harbor to conditions in West Falmouth and Phinneys Harbors and its present nitrogen levels, a nitrogen threshold of 0.35 mg/L N was determined to be supportive of eelgrass habitat in this system. This threshold should also support eelgrass in the shallower regions as well. As the east basin of Polpis Harbor has only recently lost its eelgrass and is presently 0.36 mg/L N, but has shallower waters than Head of the Harbor, only a slight reduction over present levels appears to be needed to support eelgrass habitat. Clearly the threshold must be lower than the present 0.36 mg/L N and higher than that for Head of the Harbor (0.35 mg/L N). Therefore, a threshold of 0.36 mg/L N was set for the sentinel station in Polpis Harbor. It should be noted that the Polpis Harbor threshold is well constrained by the available data, but is at the limits of the sensitivity of the MEP approach.

It is important to note that the analysis of future nitrogen loading to the Nantucket Harbor estuarine system focuses upon additional shifts in land-use from forest/grasslands to residential and commercial development. However, the MEP analysis indicates that 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. 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 Nantucket Harbor estuarine system is that protection/restoration will necessitate a very slight reduction in the present (2005) nitrogen when and where possible, and management options to negate additional nitrogen inputs in the future.

<u>Nitrogen loadings to the embayment</u>

a) Present loading rates:

In the Nantucket Harbor Embayment system overall, the highest N loadings come from benthic sediment input and atmospheric deposition with lesser amounts coming from land use and septic systems.

The total N loading from all sources was 149.5 kg/day across Nantucket Harbor Embayment. A breakdown of N loading, by source, is presented in Table 3.

**TABLE 3: Nitrogen Loading to Nantucket Harbor Embayment from within the Watershed (Land Use-Related Runoff, and Septic Systems), Sediments, and from the Atmosphere**

| Nantucket Harbor Embayment | Present Non-Wastewater Watershed Load [1] (kg/day) | Present Septic System Load (kg/day) | Benthic Input[2] (kg/day) | Present Atmospheric Deposition (kg/day) | Total Nitrogen Load from All Sources (kg/day) |
|---|---|---|---|---|---|
| Head of Harbor | 1.15 | 0.70 | 0 | 22.24 | 24.09 |
| Quaise Basin | 1.73 | 0.39 | 43.90 | 20.13 | 66.15 |
| Town Basin | 10.71 | 1.51 | 0 | 13.89 | 26.11 |
| Polpis Harbor | 3.10 | 0.43 | 27.44 | 2.19 | 33.16 |
| TOTAL | 16.69 | 3.03 | 71.34 | 58.45 | 149.51 |

[1] Composed of fertilizer, runoff, and atmospheric deposition to freshwater lakes and natural surfaces

[2] Negative benthic flux has been set to zero, as it is not a load

Controllable loadings 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 watershed N loadings to the Nantucket Harbor Embayment system, the target watershed load, and the percent reductions in N loads needed to achieve the target loads.

## 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 Nantucket Harbor 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.

**TABLE 4: Present Watershed Nitrogen Loading Rate, Target Threshold Nitrogen Loading Rate, and the Percent Reduction of the Existing Load Necessary to Achieve the Target Threshold Load**

| Embayments | Present Watershed Load [1] (kg/day) | Target Threshold Watershed Load[2] (kg/day) | Percent Watershed Load Reductions Needed to Achieve Threshold Loads |
|---|---|---|---|
| Head of Harbor | 1.86 | 0.79 | 58 % |
| Quaise Basin | 2.12 | 1.14 | 46 % |
| Town Basin | 12.22 | 10.71 | 12 % |
| Polpis Harbor | 3.52 | 2.18 | 38 % |

[1] Composed of combined fertilizer, runoff, septic system loadings, and atmospheric deposition to freshwater lakes and natural surfaces

[2] Target threshold watershed load is the load from the watershed needed to meet the target threshold N concentrations identified in Table 2 above

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:

*TMDL = BG + WLAs + LAs + 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 is included in watershed loads, but is not quantified or presented separately.

**Waste Load Allocations**

Waste load allocations identify the portion of the loading capacity allocated to existing and future point sources of wastewater, including storm water. There are no direct point source discharges to Nantucket harbor with the exception of some storm water discharges.

In the sandy soils of southeastern Massachusetts the vast majority of storm water percolates into the ground water 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 in pervious areas.

Typically, impervious areas adjacent to each embayment contribute stormwater contributions directly to the system and as such must be included in the wasteload allocation as a point source discharge. MassDEP has recognized the Town of Nantucket's storm water conveyance systems also drain extensive impervious surfaces extending inland from the shore and are also significant pollutant sources. This is especially true in the case of the Town Basin portion of the Harbor system. As a result the N load from the entire impervious surface within the watershed was used to estimate the wasteload. Using the entire impervious area from each subwatershed is considered conservative because it assumes all impervious surfaces are connected which is likely not the case thus adding to the margin of safety.

Appendix C provides the nitrogen loads from impervious surfaces (serving as an estimate of the maximum waste load) in each of the four subwatersheds covered in this report. Loadings range from 0.5 kg/day in Head of Harbor to 5.3 kg/day in Town Basin.

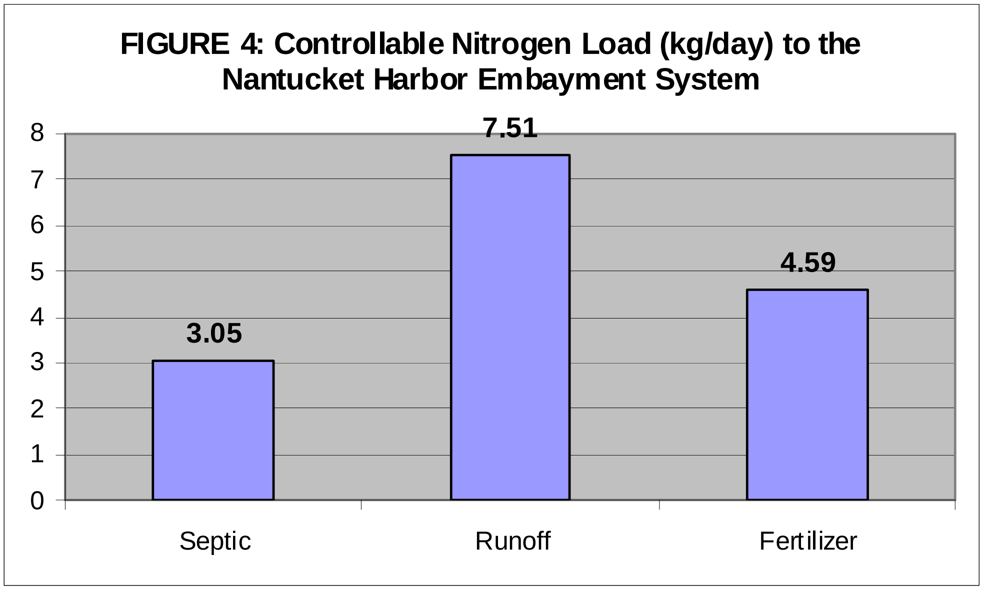
**Load Allocations**

Load allocations identify the portion of loading capacity allocated to existing and future nonpoint sources. In the case of the Nantucket Harbor Embayment system, the nonpoint source loadings from the watershed are from septic systems, runoff (stormwater), and fertilizers.

Generally, stormwater that discharges directly to the harbor would be considered a part of the wasteload allocation, rather than the non-point load allocation. As presented in Chapter IV, V, and VI, of the MEP Technical Report, and discussed above since the vast majority of stormwater percolates into the aquifer and enters the embayment system through groundwater the TMDL accounts for stormwater loadings and groundwater loadings in one aggregate allocation as a non-point source with the exception of stormwater contributed by impervious areas within the stormwater conveyance system.

The loadings from atmospheric sources incorporated into the TMDL are the same rates presently occurring, because, as discussed above, local control of atmospheric loadings, though helpful, is not adequate to improve N-impacted estuaries.

Figure 4 emphasizes the fact that although a slight majority of locally controllable N comes from runoff from impervious surfaces, loads from all the "controllable" sources are similar. Therefore that the Town may want to set priorities to reduce N loading based on "local knowledge", existing programs, and ongoing work related to their CWMP.




**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 Nantucket Harbor Embayment System TMDL is implicit, and the conservative assumptions in the analyses that account for the MOS are described below.

<u>1. Use of conservative data in the linked model</u>

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 ≥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 2 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 tidal 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 that nitrogen sources can take considerable time to migrate to impacted waters.

**TMDL Values for Nantucket Harbor 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 Nantucket Harbor Embayment system the TMDLs were calculated by projecting reductions in locally controllable on-site subsurface wastewater disposal systems and land use (runoff and fertilizers). Once again the goal of this TMDL is to achieve the identified target threshold N 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 Nantucket Harbor Embayment System, Represented as the Sum of the Calculated Target Threshold Load (from Watershed Sources), Atmospheric Deposition, and Benthic Input**

| Sub-embayment | Target Threshold Watershed Load [1] (kg/day) | Atmospheric Deposition (kg/day) | Benthic Input (kg/day) | TMDL [2] (kg/day) |
|---|---|---|---|---|
| Head of Harbor | 0.79 | 22.24 | 0 | 23 |
| Quaise Basin | 1.14 | 20.13 | 43.01 | 64 |
| Town Basin | 10.71 | 13.89 | 0 | 25 |
| Polpis Harbor | 2.18 | 2.19 | 26.45 | 31 |

[1] Target threshold watershed load is the load from the watershed needed to meet the embayment threshold concentrations identified in Table 2

[2] Sum of target threshold watershed load, atmospheric deposition load, and the benthic input load

## 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 Nantucket Harbor Embayment system. In order to achieve those target concentrations, N loading rates must be reduced throughout the harbor. Table 5, above, lists the target watershed threshold loads. If these threshold loads are achieved, this embayment system will be protected.

Nantucket has completed a Comprehensive Wastewater Management Plan (CWMP) and Environmental Impact Report (EIR) that recommend the upgrade of the existing Surfside Wastewater Treatment Facility, construction of a new Madeket WWTF, sanitary sewering of five "needs" areas, and preparation of a septage management plan for the remainder of the Island. The recommended plan is to be designed and constructed over a 12-year period.

In addition to the CWMP/EIR, the Town is mapping and evaluating its wastewater and storm water infrastructures in order to determine the rehabilitation/upgrades required based on existing and future needs.

The CWMP assesses the most cost-effective options for achieving the target N watershed loads, including: reductions in storm water runoff; the implementation of storm water BMPs; and reductions in on-site subsurface wastewater disposal system loadings by sewering and treatment for N control of sewage and septage.

Because the CWMP/EIR is a dynamic and flexible long-term planning document, the Town will have the opportunity to incorporate any additional information that is developed by the MEP or any State, Federal, or local authority, including this TMDL.

The Nantucket Landscape Association has proposed fertilizer application rates and schedules, that if followed, will minimize the amount of nitrogen leaching from the soil and into the groundwater.

Recommended slow release fertilizer rates and scheduling, are as follows:

March – mid May…………..1/2 to 1 pound / 1000 square feet
June – July………………….1/2 to 1 pound / 1000 square feet
August – September……….. 1 pound / 1000 square feet
October – November………..1/2 to 1 pound / 1000 square feet

In addition to the fertilizer application rates and scheduling recommendations, advice on optimum soil pH adjustments, watering, mowing height, soil aeration, organic matter incorporation, and dethatching practices were also provided for lawn turf management, and for the proper maintenance of trees and shrubs.

Current MEP estimates are that fertilizer makes up 30% of the controllable N source, so any successful efforts to minimize fertilizer use, and to schedule applications to maximize the uptake of N by plants, will be very worthwhile.

The Town must determine if implementation of the CWMP, in combination with other N-reducing efforts, will achieve the TMDL.

MassDEP's MEP Implementation Guidance report (http://www.mass.gov/dep/water/resources/coastalr.htm#guidance ) provides many N loading reduction strategies that are available to municipalities, and have in part been incorporated, or are being considered by Nantucket. 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 Nantucket is not 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 and listed in Table 2 and the related discussion in this 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 sub-embayments to protect near-shore 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 Town 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 non-point sources. Currently, the MassDEP is requiring remediation of N loading through a Consent Order and the Comprehensive Wastewater Management Plan (CWMP) process, as described above. In addition, because most non-point source controls are voluntary, reasonable assurance is also based on the commitment of the locality involved. Nantucket 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.

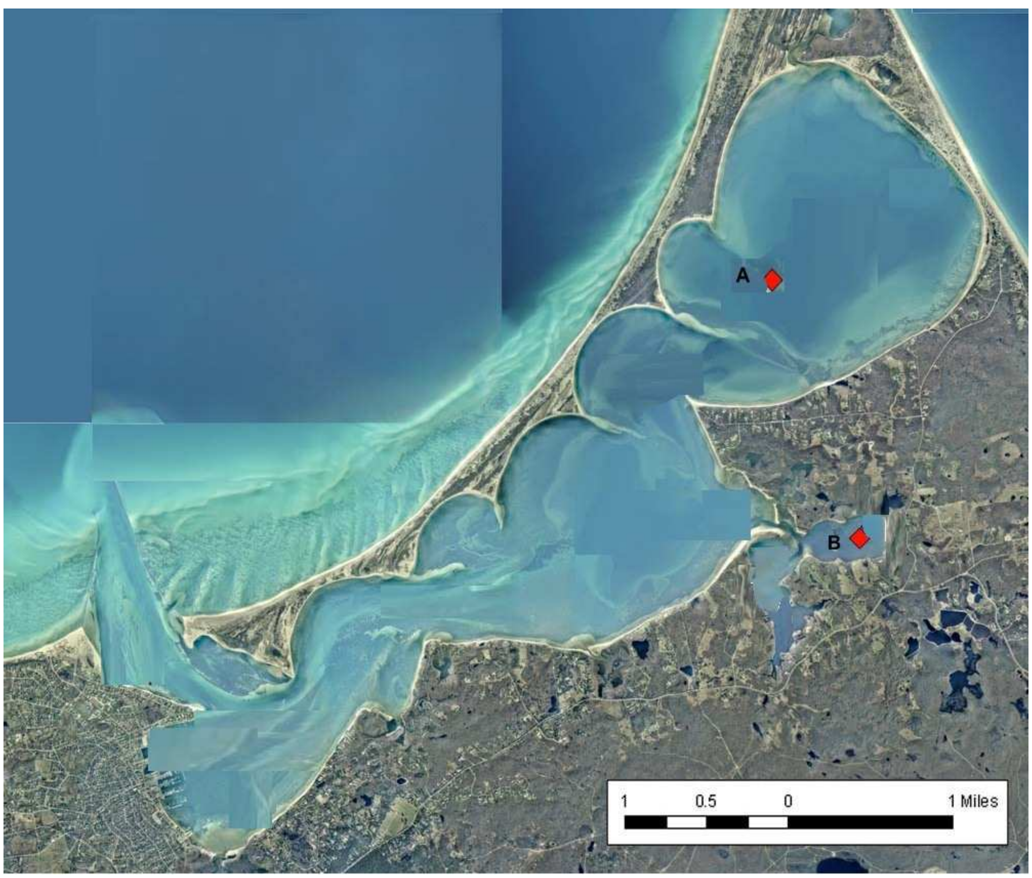
## Appendix A

**TABLE A: Nitrogen Concentrations for Nantucket Harbor Embayment System (from Chapter VI of the Accompanying MEP Technical Report)**

Table VI-1. Measured data and modeled Nitrogen concentrations for the Nantucket Harbor estuarine system used in the model calibration plots of Figures VI-2 and VI-3. All concentrations are given in mg/L N. "Data mean" values are calculated as the average of the separate yearly means. Data represented in this table were collected in the summers of 1988 through 1990 and 1992 through 1994 by the Woods Hole Oceanographic Institute (WHOI) and between 1992 and 2005 by the Town of Nantucket Marine Department.

| Sub-embayment | Monitoring Station | MEP ID | Data Mean | s.d. All Data | N | Model Min | Model Max | Model Average |
|---|---|---|---|---|---|---|---|---|
| Head of the Harbor - Upper | 2 | 2 | 0.408 | 0.188 | 81 | 0.388 | 0.405 | 0.397 |
| Head of the Harbor - Mid | Town 3 | 2.2 | 0.401 | 0.115 | 45 | 0.377 | 0.399 | 0.390 |
| Head of the Harbor - Lower | 2A | 2.1 | 0.339 | 0.070 | 46 | 0.329 | 0.377 | 0.353 |
| Pocomo Head | 3 | 3 | 0.335 | 0.081 | 74 | 0.324 | 0.361 | 0.340 |
| Quaise Basin | 3A+Town 2 | 3.1 | 0.336 | 0.112 | 98 | 0.303 | 0.339 | 0.325 |
| East Polpis Harbor | 4+Town 6 | 4 | 0.362 | 0.105 | 107 | 0.354 | 0.371 | 0.361 |
| West Polpis Harbor | 4A+Town 5 | 4.1 | 0.388 | 0.119 | 100 | 0.358 | 0.385 | 0.371 |
| Abrams Point | 5 | 5 | 0.335 | 0.060 | 39 | 0.271 | 0.322 | 0.296 |
| Monomoy | 6 | 6 | 0.297 | 0.086 | 76 | 0.282 | 0.300 | 0.291 |
| Mooring Area | 7+Town 1, 1A | 7 | 0.326 | 0.106 | 123 | 0.276 | 0.291 | 0.285 |
| Nantucket Sound | OS+Town 4 | 7.1 | 0.239 | 0.041 | 41 | - | - | - |

**Figure A: Sentinel Stations for the Nantucket Harbor System.** Station A is in the "Head of the Harbor - lower" basin, Station B is in the "East Polpis harbor".



## Appendix B

**TABLE B: Summary of 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.** Threshold "A" represents a scenario in which 100% of the septic load was removed in Town Basin and 80% septic removed from all other basins. This was the preferred alternative. Threshold B represents a scenario in which 100% of the septic load would be removed from the entire watershed of Nantucket Harbor.

This information may be modified as a result of ongoing Nantucket Board of Health septic system inspection and upgrade regulations in the Nantucket Harbor embayment system watershed.

Table VIII-2. Comparison of sub-embayment watershed ***septic loads*** (attenuated) used for modeling of present and threshold loading scenarios of the Nantucket Harbor 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 "A" Septic Load (kg/day) | Threshold "A" Septic Load % Change | Threshold "B" Septic Load (kg/day) | Threshold "B" Septic Load % Change |
|---|---|---|---|---|---|
| Head of the Harbor | 0.705 | 0.141 | -80.0% | 0.000 | -100.0% |
| Polpis Harbor | 0.435 | 0.087 | -80.0% | 0.000 | -100.0% |
| Quaise Basin | 0.392 | 0.078 | -80.0% | 0.000 | -100.0% |
| Town Basin | 5.194 | 0.000 | -100.0% | 0.000 | -100.0% |
| System Total | 6.726 | 0.306 | -95.4% | 0.000 | -100.0% |

## Appendix C

**TABLE C: The Nantucket Harbor Embayment System Estimated Waste Load Allocation (WLA) from Runoff of Impervious Areas Within Each Sub-watershed**

| Sub-watershed Name | Total Sub-watershed Impervious areas | | Total Impervious Subwatershed load (WLA) | Total Subwatershed load |
|---|---|---|---|---|
| | Acres | % | Kg/year (Kg/day) | Kg/year |
| Head of Harbor | 60.9 | 6.5 | 174 (0.5) | 8795 |
| Quaise Basin | 88.5 | 6.3 | 246 (0.7) | 8121 |
| Town Basin | 445.8 | 15.1 | 1931 (5.3) | 9530 |
| Polpis Harbor | 134.2 | 5.1 | 393 (1.1) | 2087 |
| Total | 729.4 | 8.85 | 2744 (7.6) | 28,533 |

# Appendix D

## TABLE D: Four Total Nitrogen TMDLs

| Embayment | Segment ID | Description | Sub-Embayment | TMDL (kg/day) |
|---|---|---|---|---|
| **Nantucket Harbor** (Split into three sub-embayments for the purposes of this study) | MA97-01_2004 | Previously determined to be impaired for nutrients, pathogens, and noxious aquatic plants by MassDEP. | **Head of Harbor** | 23 |
| | | | **Quaise Basin** | 64 |
| | | | **Town Basin** | 25 |
| **Polpis Harbor** | MA97-26_2004 | Previously determined to be impaired for nutrients, pathogens, and other habitat alterations by MassDEP. | | 31 |