Final
Waquoit Bay System; including Eel Pond, Quashnet River, Hamblin Pond, and Jehu River
Total Maximum Daily Loads for Total Nitrogen
(CN 378.1)

COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENERGY AND ENVIRONMENTAL AFFAIRS
KATHLEEN THEOHARIDES, SECRETARY
MASSACHUSETTS DEPARTMENT OF ENVIRONMENTAL PROTECTION
MARTIN SUUBERG, COMMISSIONER
BUREAU OF WATER RESOURCES
KATHLEEN BASKIN, ASSISTANT COMMISSIONER
June 2020

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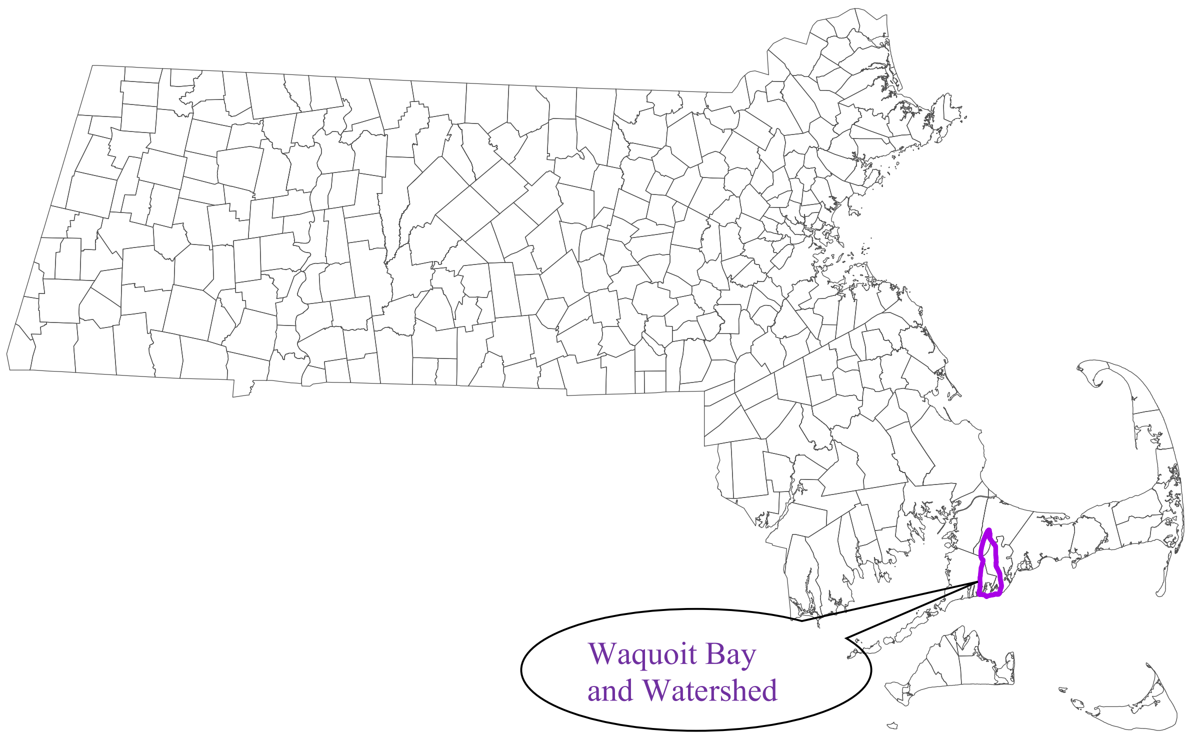

Key Feature:	Total Nitrogen TMDL for Waquoit Bay and Eel Pond
Location:	Environmental Protection Agency **(**EPA) Region 1
Land Type:	New England Coastal
303d Listing:	According to the 2016 Integrated List of Waters: Waquoit Bay (MA96-21) is in Category 5, impaired for Estuarine Bioassessments and Oxygen (Dissolved). Quashnet River (MA96-20), Hamblin Pond (MA96-58), Little River (MA96-61), and Jehu Pond (MA96-59) are in Category 4a for completed Estuarine Bioassessments and Nitrogen (Total) TMDLs. Hamblin Pond (MA96-58) and Quashnet River (MA96-20) are also in Category 4a for a completed Fecal Coliform TMDL. Quashnet River (MA96-90) Eel Pond and Childs River (freshwater and marine segments) to be evaluated for inclusion in a future Integrated List of Waters.
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 Mashpee, Town of Falmouth
Data Mechanism:	Massachusetts Surface Water Quality Standards, Ambient Data, and Linked Watershed Model
Monitoring Plan:	Towns of Sandwich, Mashpee and Falmouth monitoring programs (assistance from SMAST)
Control Measures:	Sewering, Storm Water Management, Fertilizer Use By-laws

Executive Summary

Problem Statement

Excessive nitrogen (N) originating primarily from on-site wastewater has led to significant decreases in the environmental quality of coastal rivers, ponds, and harbors in many communities in southeastern Massachusetts. In the Towns of Falmouth, Mashpee, and Sandwich the problems in coastal waters include:

- Loss of eelgrass beds, which are critical habitats for macroinvertebrates and fish;
- Periodic extreme decreases in dissolved oxygen concentrations that threaten aquatic life;
- Undesirable increases in macro-algae, which are much less beneficial than eelgrass;
- 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 Falmouth, Mashpee, and Sandwich 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 could result in further loss of eelgrass and possible increases in 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 further loss of benthic macroinvertebrates throughout most of the embayments. As a result of these environmental impacts, commercial and recreational uses of Waquoit Bay 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
  - Stormwater Runoff
  - Non-golf course and golf course fertilizers
  - Wastewater treatment facilities
- Atmospheric deposition
- Nutrient-rich bottom sediments in the embayments

Figure ES-A and Figure ES-B illustrate the percent contribution of all the watershed sources of N and the controllable N sources to the estuary system, respectfully. Values are based on Table IV-3 and Figure IV-3 from the Massachusetts Estuaries Project (MEP) Technical Report (Howes *et. al* 2013). As evident, most of the present *controllable* load to this system comes from septic systems (wastewater).

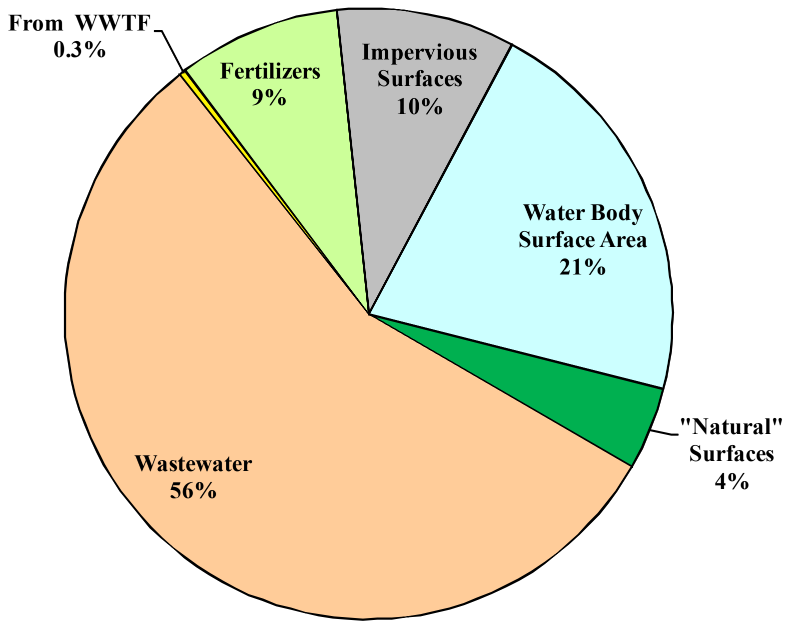

Figure ES-A: Percent Contributions of All Watershed Nitrogen Sources to the Waquoit Bay Embayment System

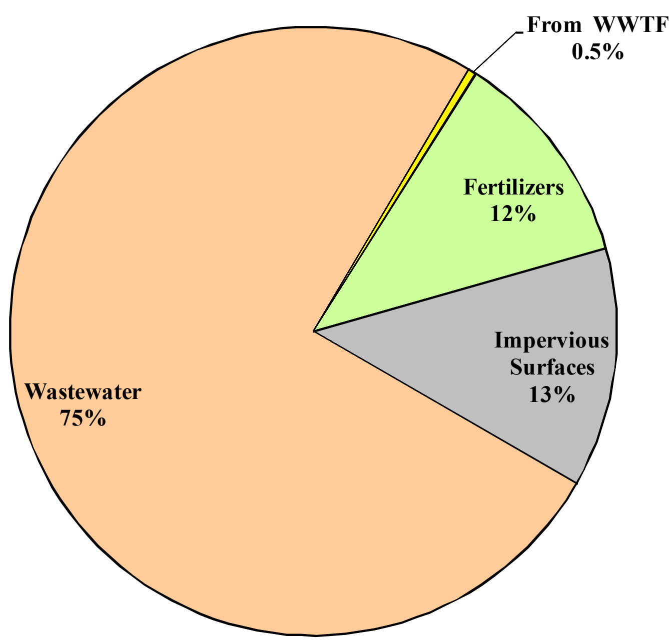

Figure ES-B: Percent Contributions of Controllable Watershed Nitrogen Sources to the Waquoit Bay Embayment System

Target Threshold Nitrogen Concentrations and Loadings

The Waquoit Bay embayment system and contributing watershed is located within the towns of Mashpee, Falmouth, and Sandwich. The Present Watershed N load (the quantity of controllable watershed sources of nitrogen) to the Waquoit Bay embayment system is 90.87 kg/day (Table ES-1, Howes *et al*, 2013). The Target Watershed N Load to meet habitat restoration targets is 42.3 kg/day; an overall reduction of 53.4%. The average annual concentration of N in the sub-embayments ranged from 0.39 mg/L (milligrams per liter) in lower Waquoit Bay to 1.19 mg/L in the upper Childs River. The average of yearly means at nineteen stations collected from 2002 through 2010 is reported in Table VI-1 of the MEP Technical Report (Howes *et al* 2013) and included as Appendix B of this report.

In order to restore and protect the Waquoit Bay sub-embayments, the N loadings, and subsequently the concentrations of N in the water, must be reduced to levels below the thresholds 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 is to reach this target threshold concentration, as it has been determined for each impaired waterbody segment. The Massachusetts Estuaries Project (MEP) has determined that for the Waquoit Bay sub-embayments, target threshold N concentrations at the sentinel stations in the range of 0.374 mg/L to 0.5 mg/L are protective of water quality standards. The mechanism for achieving these target threshold N concentrations is to reduce the N loadings to the sub-embayments. Based on sampling and modeling analysis and the resulting Technical Report the MassDEP has determined that the Total Maximum Daily Loads (TMDL) of N that will meet the target threshold concentrations range from 2.09 to 32.2 kg/day within the Waquoit Bay embayment system (Appendix D). A total of nine TMDLs and three Pollution Prevention TMDLs have been developed with a total load for the entire system of 120.02 kg/day. The purpose of this document is to present TMDLs for each sub-embayment and to provide guidance to the watershed Towns of Falmouth, Mashpee and Sandwich, on possible ways to reduce the N loadings to within the recommended TMDLs and protect the waters of this embayment system.

This TMDL supersedes the previously approved TMDL for the Quashnet River, Hamblin Pond and Jehu Pond, EPA TMDLs #33811-33815 and MassDEP Control Number 218.0. Additional modeling completed as part of this TMDL required changes to the boundary conditions in Waquoit Bay used to establish the TMDLs approved in 2007 for the Quashnet River, Hamblin Pond and Jehu Pond.

Implementation

The primary goal of the TMDL implementation will be lowering the concentrations of N in Waquoit Bay embayment system. The MEP linked model has shown that by reducing the loadings from on-site subsurface wastewater disposal systems in the watershed by 76% the target threshold concentrations can be met. It is important to note that there is a variety of loading reduction scenarios that could achieve the target threshold N concentration.

Local officials can explore other loading reduction scenarios through additional modeling as part of their Comprehensive Wastewater Management Plan (CWMP). Implementing best management practices (BMPs) to reduce N loadings from fertilizers and runoff where possible will also help to lower the total N load to the system. Methodologies for reducing N loadings from septic systems, stormwater runoff and fertilizers, are explained in detail in the "MEP Embayment Restoration Guidance for Implementation Strategies", that is available on the

MassDEP website https://www.mass.gov/files/documents/2016/08/rz/mepmain.pdf. 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. This adaptive management approach will incorporate the priorities and concepts included in the updated area wide management plan established under Clean Water Act Section 208. Finally, growth within the communities of Mashpee, Falmouth, and Sandwich (part of the upper watershed only) which 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 that are not meeting 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 these pollutants of concern, taking into consideration all contributing sources to that water body, while allowing the system to 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 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 that 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 Waquoit Bay System, the pollutant of concern for this TMDL (based on observations of eutrophication), is the nutrient nitrogen (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 which impair eelgrass beds and imperil the healthy ecology of the affected water bodies.

The TMDLs for total N for the Waquoit 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, the Towns of Sandwich, Mashpee and Falmouth and others, as part of the Massachusetts Estuaries Project (MEP). The data was collected over a study period from 2002-2010. This study period will be referred to as the "Present Conditions" in the TMDL since it is the most recent data available. The MEP Technical Report can be found at https://www.mass.gov/doc/waquoit-bay-eel-pond-embayment-system-falmouth-mashpee-ma-2013. The MEP Technical Report presents the results of the analyses of the sub-embayments 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. Critical elements of this approach are 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 within this estuarine system. 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 target threshold N concentration generated for this embayment. Thus, the MEP offers a science-based management approach to support the wastewater management planning and decision-making process in the Towns of Falmouth, Mashpee and Sandwich.

Description of Water Bodies and Priority Ranking

Watershed Characterization

The Waquoit Bay System in Falmouth, Mashpee, and Sandwich Massachusetts, at the southwestern edge of Cape Cod, faces Nantucket Sound to the south, and consists of several sub-embayments of varying size and hydraulic complexity, characterized by limited rates of flushing, shallow depths and heavily developed watersheds. The sub-embayments studied constitute important components of each of the towns' natural and cultural resources.

The United States Geological Survey (USGS), using groundwater models has delineated a Waquoit Bay system watershed area of approximately 23.5 square miles. The delineated contributory watershed included 48 subwatersheds (Figure 1, Howes *et. al,* 2013, pg. 38). It is estimated that the daily average groundwater discharge is 3,495,522 cfs/day for the entire system. The three towns of Falmouth, Mashpee and Sandwich comprise 30%, 52% and 18% of the watershed by land area, respectively.

The MEP project has assessed landuse in the Waquoit Bay system using Town of Falmouth, Sandwich and Mashpee assessor's data. Landuse was summarized into ten categories including residential, commercial, industrial, agricultural, multi-use, undeveloped, open space, public service/government (including road rights-of-way), recreational (golf courses) and properties without assessor's land use codes. The landuse summary follows Massachusetts Department of Revenue classifications (MassDOR 2009) and the public service category signifies tax exempt properties including land owned by government and private non-profits. The most common landuse categories are public service and residential which compromised 48% and 25% of the overall Waquoit Bay system watershed respectively (Howes *et. al* 2013, pg. 46). The MEP project team estimates that parcels classified as developable represent 11% of the watershed area.

Waquoit Bay has been designated an Area of Critical Environmental Concern (ACEC), including, the eastern shore of the Childs River and Seapit River, all of the saltwater reaches and portions of the freshwater reaches of the Quashnet River, Hamblin Pond, Jehu Pond, Great River, and Sage Lot Pond. Waquoit Bay including the areas just described and the salt water portion of the Childs River and Seapit River has been designated as Priority Habitat of Rare Species and Estimated Habitat of Rare Wildlife by the Natural Heritage and Endangered Species Program (NHESP) of the Massachusetts Division of Fish and Game. Waquoit Bay is part of the National Oceanic and Atmospheric Association's (NOAA) National Estuarine Research Reserve program.

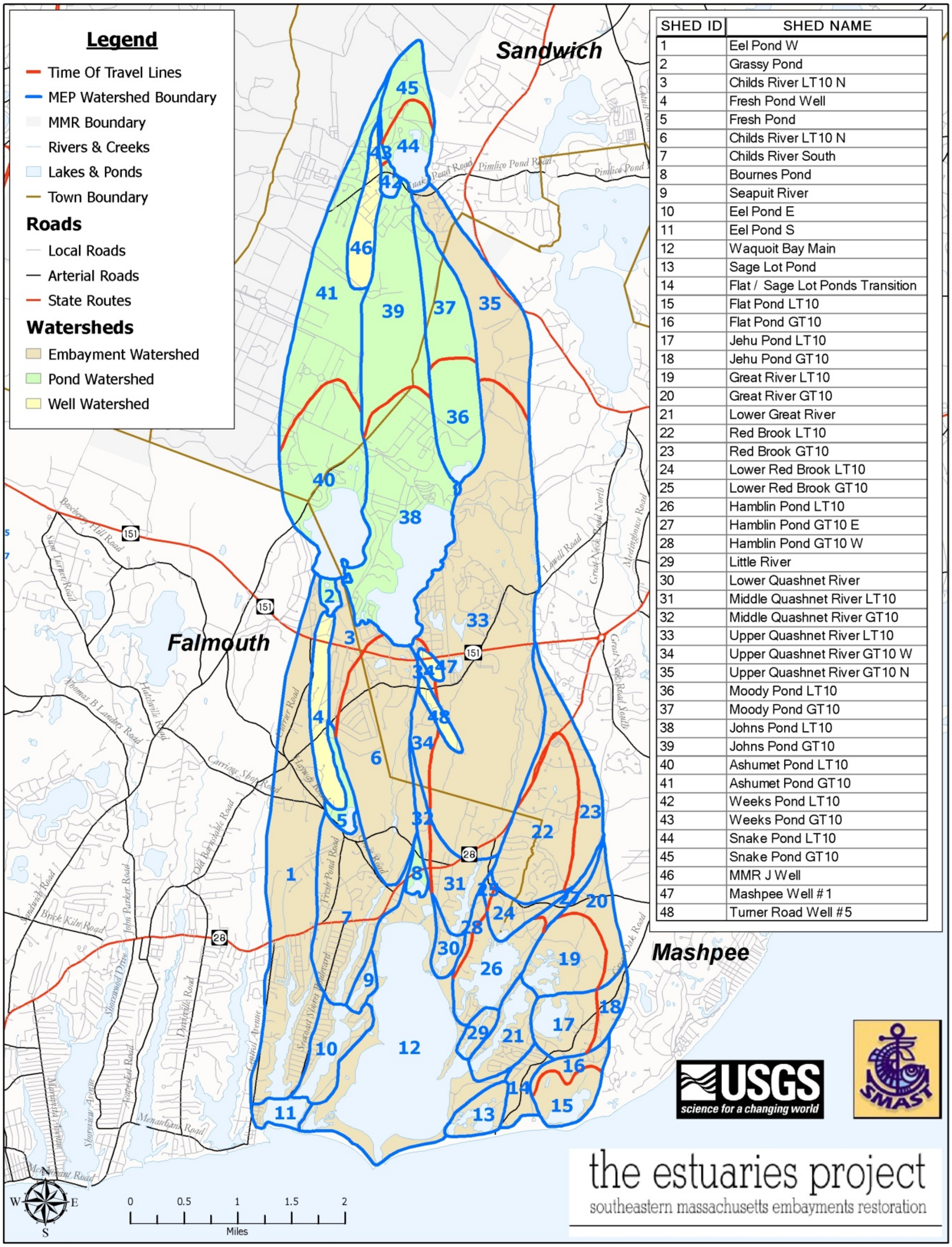


Figure 1: USGS Watershed Delineation for the Waquoit Bay System during MEP project (excerpted Howes *et. al*, 2013, pg 38)

Description of Waterbodies

Waquoit Bay is an approximately 825-acre embayment located in Falmouth on Cape Cod. Waquoit Bay is generally shallow with an average depth less than 3 feet. Waquoit Bay has a number of tributary subembayments including Quashnet River, Hamblin Pond, Little River, Great River and Jehu Pond (Figure 2). The major sources of freshwater include Childs River, Quashnet River, Red Brook and groundwater flows. Salt water enters Waquoit Bay from Vineyard Sound through a maintained inlet and through the Eel Pond inlet. The main inlet to Waquoit Bay is fixed with jetties.

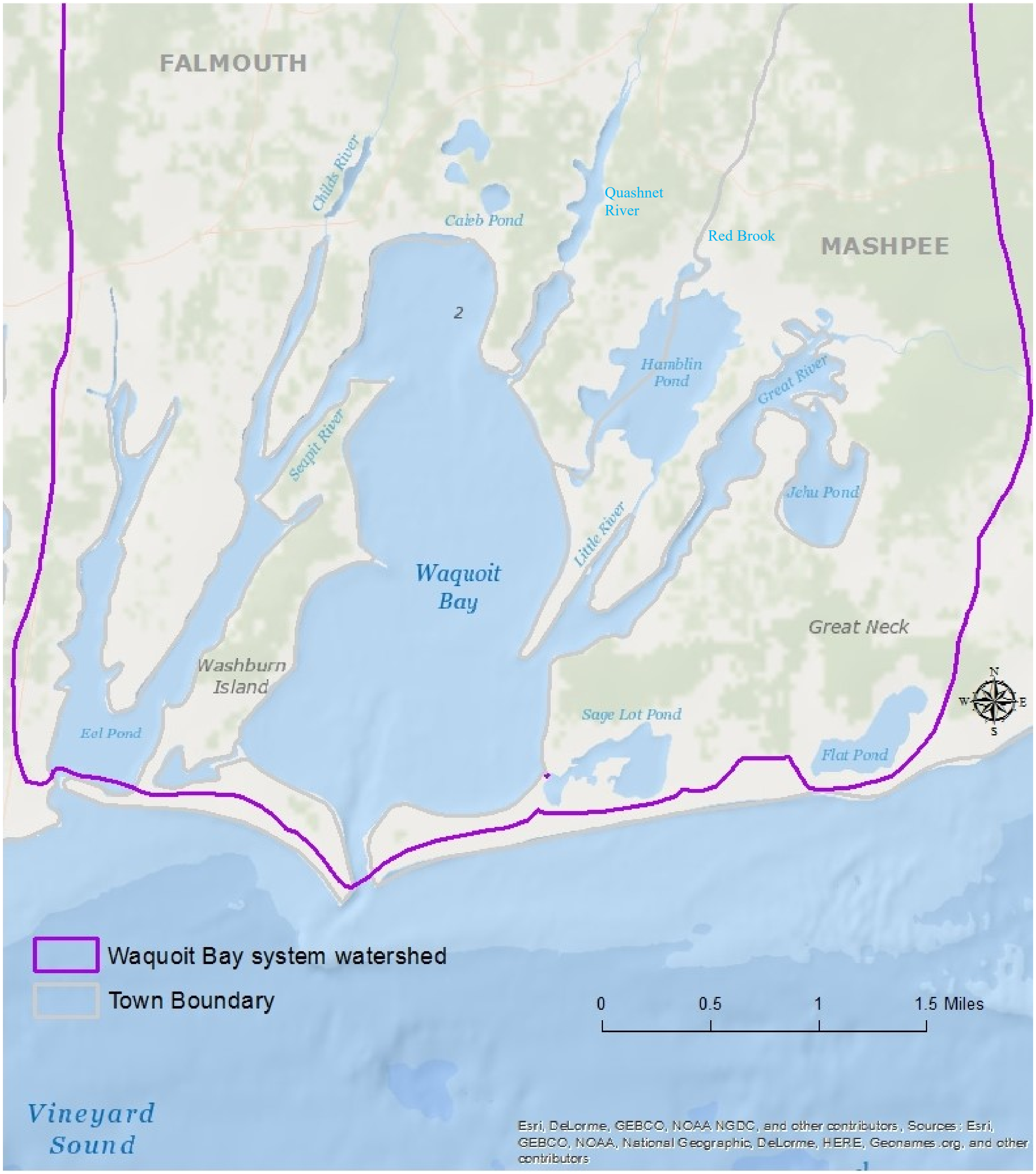


Figure 2: Overview of Waquoit Bay System

Eastern Embayments:

Quashnet River is an approximately 44-acre tidal river that enters Waquoit Bay on its north east side. The saltwater portions of Quashnet River are located in Falmouth while the freshwater portions of the river are largely located in Mashpee. The Quashnet River supplies approximately 25% of the total freshwater flows to Waquoit Bay. The outlet of the Quashnet River is believed to be "periodically occluded by transported sands" (Howes *et. al*, 2013, pg 11). Hamblin Pond, a glacial kettle pond, is an approximately 145-acre saltwater pond with significant fringing saltwater wetlands. Little River is an approximately 13 acres tidal river which connects Hamblin Pond to Waquoit Bay. Jehu Pond, a glacial kettle pond, is an approximately 55-acre saltwater pond located in the town of Mashpee. Great River is an approximately 98-acre tidal river in the town of Mashpee which connects Jehu Pond to Waquoit Bay. Sage Lot Pond is an approximately 36-acre saltwater pond/salt marsh located in the town of Mashpee (Figure 3).

Western Embayments

Eel Pond – west branch is an approximately 72-acre tidal river located in Falmouth. Childs River is an approximately 37-acre tidal river in Falmouth and is a tributary to Eel Pond – east branch. Eel Pond – east branch as defined during the MEP project is an 82-acre tidal embayment, which includes inputs from the Childs River and Seapit River. Eel Pond- south basin is an approximately 54-acre tidal basin located in Falmouth which receives inputs from Eel Pond – east and west branches (Figure 4). The armored inlet to Eel Pond – south basin (near Holt Street) provides tidal exchange with Vineyard Sound.

The nature of enclosed sub-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.

A more complete description of all the sub-embayments is presented in Chapters I and IV of the MEP Technical Report from which the majority of the following information is drawn. Howes *et. al*, 2013, Chapters VI and VII of the MEP Technical Report provide data that show that the water and habitat quality in portions of the Waquoit Bay system are impaired due to elevated nutrients, low dissolved oxygen levels, elevated chlorophyll *a* levels, macroalgae, eelgrass loss and degraded benthic fauna habitat (Table 1).

TMDLs were prepared for all waterbody segments within the sub-embayments listed below.

Waquoit Bay System sub-embayments in this system, estuarine, unless otherwise indicated:

- Waquoit Bay shoreline
- Childs River – upper
- Eel Pond – east branch
- Eel Pond – south basin
- Eel Pond - west branch
- Sage Lot Pond
- Hamblin Pond/Little River
- Jehu Pond/Great River
- Quashnet River
- Childs River (freshwater)
- Quashnet River (freshwater)
- Red Brook (freshwater)

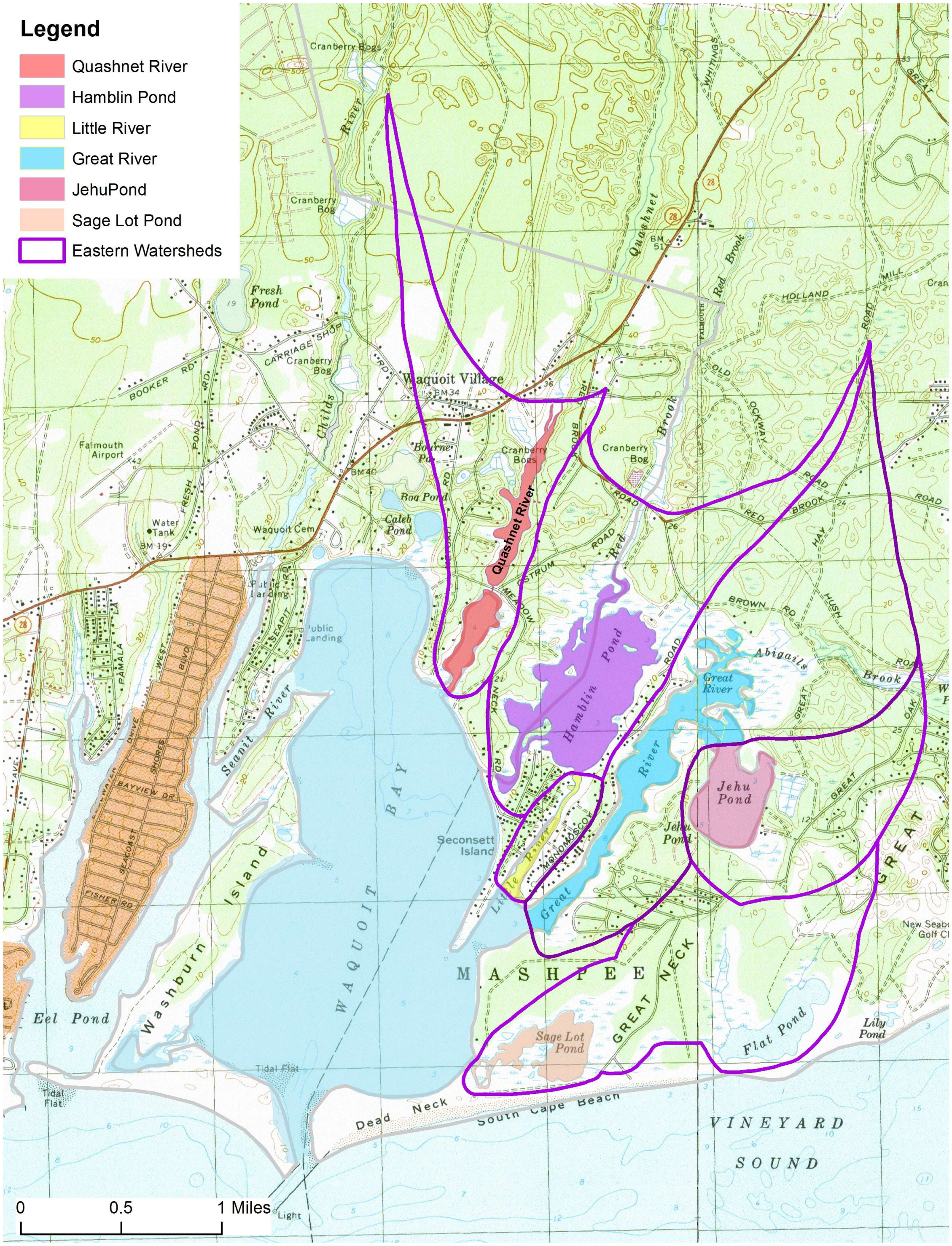


Figure 3: Waquoit Bay Eastern MEP subembayments study area

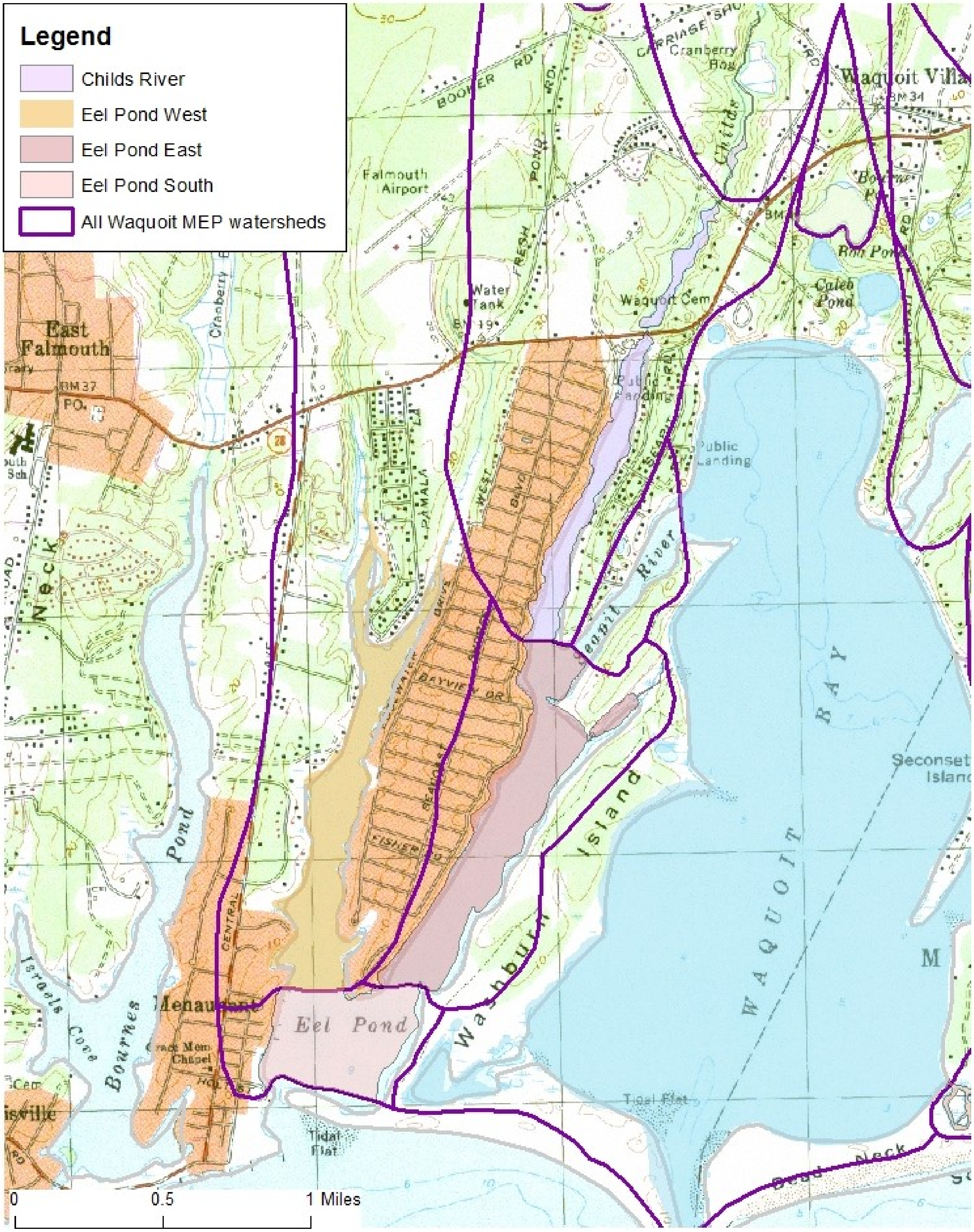


Figure 4: Waquoit Bay Western MEP subembayments study area

Priority Ranking

The embayments addressed by these TMDLs are determined to be high priorities based on three significant factors: (1) the initiative that the Towns have taken to assess the conditions of the entire Waquoit embayment system; (2) the commitment made by the Towns to restoring and preserving the sub-embayments; and (3) the extent of impairment in the embayments. In particular, these sub-embayments are 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. 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 (Howes *et. al*, 2013).

Description of Hydrodynamics of the Waquoit Bay System

Tidal water enters system through an armored inlet into the main Waquoit Harbor as well as through the Eel Pond inlet. The MEP project has evaluated the tidal circulation and flushing characteristics of this embayment system using both direct measurements and the RMA-2 model, a well-established model for estuaries. Using direct measurement of the tides at six locations in the embayment system and one offshore location in Vineyard Sound, Howes *et. al* (2013) determined there was tidal dampening with a delay of the main tidal constituent (known as M2) that ranged from 23 minutes in Waquoit Bay to 75 minutes in Hamblin Pond.

The MEP project found that around 70% of the changes in water surface elevation in the Waquoit Bay system were due to tidal processes with approximately 30% due to non-tidal processes. They concluded that the results indicate that "hydrodynamic circulation within in each of the embayments is dependent primarily upon tidal processes, with a secondary, but significant contribution from wind forces (Howes *et. al*, 2013, pg. 99). The MEP project determined a system residence time of 2.2 days for this system.

(continued next page)

Table 1: Comparison of Waquoit Bay System MEP Waterbodies with MA 2016 Integrated List and SMAST Impaired Parameters

Waquoit Bay System MEP Subembayment	MassDEP Segment Number	MassDEP Segment Description	Class	2016 Integrated List Category (Cause)	SMAST Impaired Parameter[1]	Size [2] (mi^2)
Waquoit Bay	MA96-21	From mouths of Seapit River, Quashnet River (also known as Moonakis River), Falmouth and Great River, Mashpee to confluence with Vineyard Sound, Falmouth/Mashpee.	SA, ORW	5 (Estuarine Bioassessments, Oxygen, Dissolved)	Dissolved oxygen, Chlorophyll *a*, Macroalgae, Eelgrass, Benthic Fauna	1.42
Seapit River	MA96-122	From confluence of Childs River and Eel Pond, Falmouth to inlet Waquoit Bay, Falmouth.	SA, ORW, SFO			0.05
Childs River - upper	MA96-120	From confluence with fresh water portion south of Barrows Road, Falmouth to mouth at confluence with Seapit River, Falmouth (area within Waquoit Bay ACEC designated as ORW).	SA, ORW, SFO		Dissolved oxygen, Chlorophyll *a*, Macroalgae, Eelgrass, Benthic Fauna	0.06
Eel Pond - east	MA96-121				Dissolved oxygen, Chlorophyll *a*, Macroalgae, Eelgrass, Benthic Fauna	
Eel Pond - south	MA96-121				Chlorophyll *a*, Eelgrass, Benthic Fauna	
Eel Pond - west	MA96-121	Falmouth	SA, ORW, SFO		Dissolved oxygen, Chlorophyll *a*, Macroalgae, Benthic Fauna	0.32

Table 1 (continued): Comparison of Waquoit Bay System MEP Waterbodies with MA 2016 Integrated List and SMAST Impaired Parameters

Waquoit Bay System MEP Subembayment	MassDEP Segment Number	MassDEP Segment Description	Class	2016 Integrated List Category (Cause)	SMAST Impaired Parameter[1]	Size [2] (mi^2)
Quashnet River[3]	MA96-20	Just south of Route 28, Falmouth to mouth at Waquoit Bay, Falmouth. Also known as Moonakis River.	SA, ORW	4a (Nitrogen (Total) , Oxygen, Dissolved [EPA TMDL#33811] Fecal Coliform [EPA TMDL#33812])	Dissolved oxygen, Chlorophyll *a*, Macroalgae, Eelgrass, Benthic Fauna	0.07
Hamblin Pond [3]	MA96-58	From inlet of Red Brook, Falmouth/Mashpee to outlet of Little River, Mashpee and inlet/outlet of Waquoit Bay west of Meadow Neck Road, Falmouth/Mashpee.	SA, ORW	4a (Nitrogen (Total), Estuarine Bioassessments [EPA TMDL#33812], Fecal Coliform [EPA TMDL#36771])	Dissolved oxygen, Chlorophyll *a*, Eelgrass, Benthic Fauna	0.19
Little River[3]	MA96-61	From outlet of Hamblin Pond, Mashpee to the Great River, Mashpee.	SA, ORW	4a (Nitrogen (Total), Estuarine Bioassessments [EPA TMDL#33813])	Dissolved oxygen, Chlorophyll *a*, Eelgrass	0.02
Jehu Pond[3]	MA96-59	Mashpee.	SA, ORW	4a (Estuarine Bioassessments, Nitrogen (Total) [EPA TMDL#33814])	Dissolved oxygen, Chlorophyll *a*, Eelgrass, Benthic Fauna	0.09
Great River[3]	MA96-60	From inlet of Abigails Brook, Mashpee to Waquoit Bay (excluding Jehu Pond), Mashpee.	SA, ORW	4a (Estuarine Bioassessments, Nitrogen (Total) [EPA TMDL#33815])	Dissolved oxygen, Chlorophyll *a*, Eelgrass, Benthic Fauna	0.16
Sage Lot Pond	MA96-119	West of Great Oak Road, Mashpee (segment includes tidal channels to Waquoit Bay).	SA, ORW, SFO		Chlorophyll *a*, Macroalgae, Eelgrass, Benthic Fauna	0.06

Table 1 (continued): Comparison of Waquoit Bay System MEP Waterbodies with MA 2016 Integrated List and SMAST Impaired Parameters

Waquoit Bay System MEP Subembayment	MassDEP Segment Number	MassDEP Segment Description	Class	2016 Integrated List Category (Cause)	SMAST Impaired Parameter[1]	Size [2] (mi^2)
Freshwater						
Childs River	MA96-98	Headwaters outlet Johns Pond, Mashpee to confluence with tidal portion south of Barrows Road, Falmouth (area within Waquoit Bay ACEC designated as ORW).	B, ORW		Not impaired for Nitrogen (total)	2.4 mi
Quashnet River	MA96-90	Headwaters, outlet Johns Pond, Mashpee to just south of Route 28, Falmouth.	B, ORW	2	Not impaired for Nitrogen (total)	4.1 mi
Red Brook	MA96-25	From dam at Red Brook Road, Falmouth/Mashpee to Hamblin Pond, Falmouth/Mashpee.	B, ORW	2	Not impaired for Nitrogen (total)	0.01

[1] As determined by the MEP Waquoit Bay study and reported in the MEP Technical Report (Howes et al, 2013).

[2] Size in square miles unless otherwise noted for length of river miles.

[3] This TMDL will supersede previously approved TMDLs for these subembayments. The total nitrogen load for each was revised as a result of the MEP study for Waquoit Bay.

Problem Assessment

The watersheds of Waquoit Bay's embayments have all 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 1951 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 Sandwich, Mashpee and Falmouth, as with all of Cape Cod, has increased steadily since the 1940's. The increase in year-round residents is illustrated in Figure 5 which based on U.S. Census Bureau data.

Prior to the 1950's there were fewer homes and many of those were seasonal. 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 the studied sub-embayments generally include periodic decreases of dissolved oxygen, decreased diversity of benthic animals and periodic algal blooms. Eelgrass beds, which are critical habitats for macroinvertebrates and fish, are greatly diminished in these waters. All the sub-embayments within the Waquoit Bay embayment system, which historically supported eelgrass (as evidenced by 1951 aerial photography), have shown between 89% and 99% loss of eelgrass.

Coastal communities, including Sandwich, Mashpee and Falmouth, 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.

Habitat and water quality assessments were conducted on each sub-embayment based upon available water quality monitoring data, analysis of historical changes in eelgrass distribution, time-series water column dissolved oxygen measurements, chlorophyll-a measurements, benthic community structure assessments and sediment characteristics. The sub-embayments in this study display a range of habitat quality. In general, the habitat quality of the sub-embayments studied is highest near the tidal inlet on Waquoit Bay and poorest in the most inland tidal reaches. This is indicated by gradients of the various indicators as discussed in the paragraphs below and in Table 2. Nitrogen concentrations are highest inland and lowest near the mouths. Eelgrass mapping has shown dramatic reductions from the original 1951 survey.

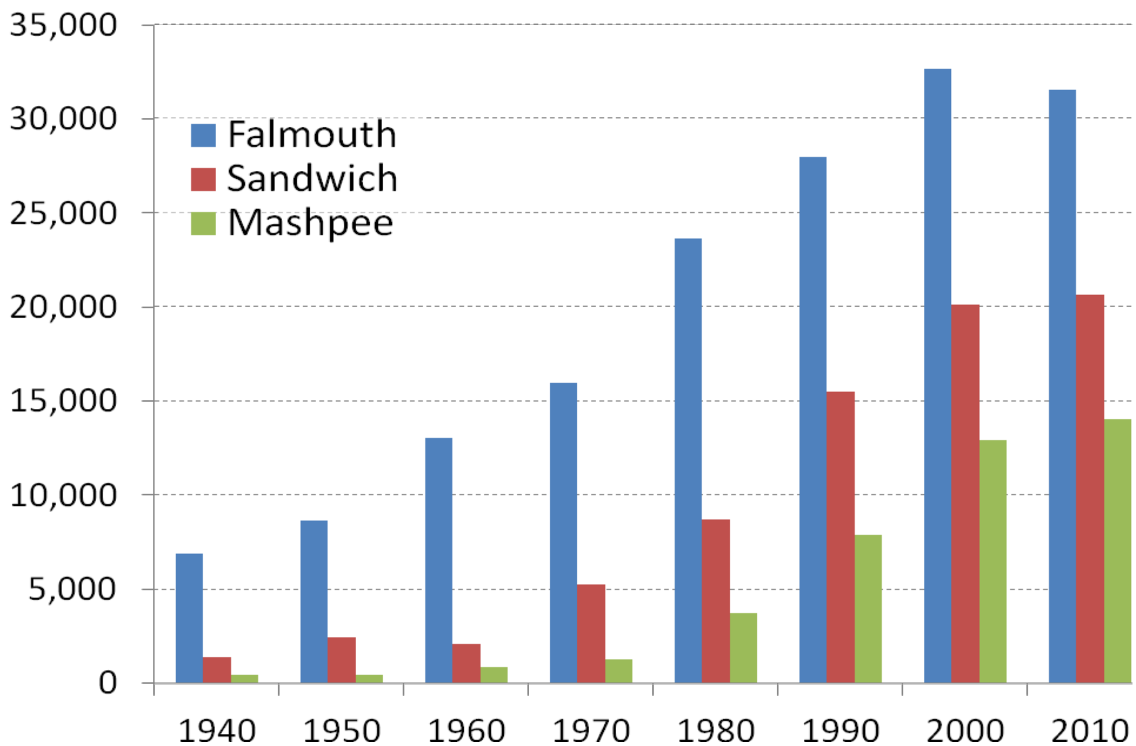


Figure 5: Towns of Falmouth, Sandwich and Mashpee Resident Population (United States Census Bureau)

Eastern Embayments

The Quashnet River was found to be significantly impaired for dissolved oxygen with dissolved oxygen less than 5 mg/L for approximately 21% of the MEP deployment. Elevated chlorophyll *a* concentrations were also found in the Quashnet River with a chlorophyll *a* geomean > 20 ug/L at two of three of MEP sampling stations (# of samples, n=11). Phytoplankton biomass was lower in the lower basin (geometric mean 9.7 ug/L, n=11). The spatial pattern of dissolved oxygen stress appears correlated with phytoplankton abundances. Eelgrass is believed to have been lost prior to 1951 in the Quashnet River. The benthic infaunal community in the Quashnet River was found to be severely degraded supporting limited numbers of one species.

The dissolved oxygen records for Hamblin Pond indicates moderate level of oxygen stress (dissolved oxygen <5 mg/L for 11% of MEP deployment. Jehu Pond was found to have moderate levels of chlorophyll *a* (geometric mean at MEP station was 7.4 ug/L, n=11). An approximate 95% loss of eelgrass by area has been documented for Hamblin Pond between 1995 and 2001. Recent MassDEP sampling (2010-2013) has not documented eelgrass in the pond.

The Little River has a near complete loss of eelgrass. MassDEP (Howes *et al* 2013) indicates that eelgrass beds lost from this reach of tidal river occurred between 1951 and 1995. Short and Burdick (1996) documented limited eelgrass in Little River in the late 1980s. The MEP project found a healthy benthic community with high diversity in the single sampling station in the Little River.

Jehu Pond showed a high level of oxygen depletion, to a level, which will significantly impair habitat quality. Dissolved oxygen levels measured during the MEP project periodically approached anoxia. Moderate chlorophyll *a* levels were documented by the MEP with a geometric mean of 11.9 ug/L at the MEP station (n=12). An approximate 89% loss of eelgrass between 1951 and 2001 has been noted. Some recent increase in eelgrass around the margin of Jehu Pond was documented in 2010 (MassDEP 2014). In addition, the MEP found the benthic infaunal community to be impacted. The upper and mid Jehu Pond MEP stations were found to have low number of individuals, low species richness and low diversity.

The Great River has lost all of its eelgrass beds. Short and Burdick (1996) documented eelgrass coverage that ranged between 0.15 km^2 and 0.05 km^2 between 1987 and 1992, respectively. In 1995, MassDEP documented eelgrass coverage of approximately 0.1 km^2. MassDEP analysis in 2001 and 2010 found no eelgrass. The MEP project found that the benthic community in the Great River although better than Jehu Pond was moderately impacted.

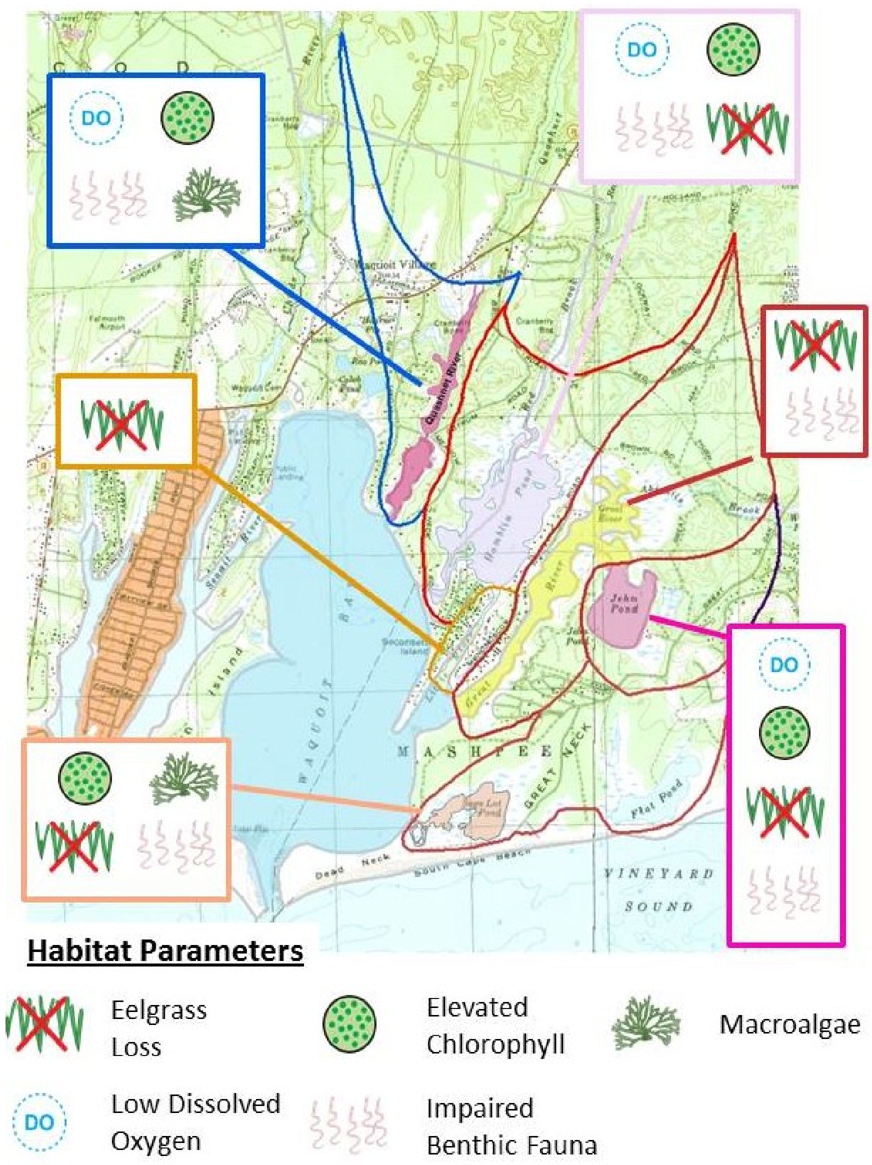
The MEP study found Sage Lot Pond to be moderately impaired due to the significant presence of macroalgae and a moderately impaired benthic community. The MEP noted moderate chlorophyll *a* level and documented accumulations of red branched macroalgae noting moderate to high coverage. The MEP found small beds of eelgrass with moderate density but noted that it was often covered with moderate to heavy amounts of epiphytes. The MEP study reported a moderately impacted benthic community with limited species richness, mainly crustaceans which are considered atypical for salt marsh basins as well as some stress indicators (i.e. *Capitella*). The observed low dissolved oxygen (4 mg/L) is considered typical of the organically enriched nature of tidal creeks and salt marshes, such as Sage Lot Pond.

Main Basin

It should be noted that conditions at the "inlet" location are the highest quality within the main basin of Waquoit Bay. The water quality indicators that are central to evaluating the nutrient related habitat health for eelgrass and benthic infaunal communities are the degree of oxygen depletion in bottom waters and the level of phytoplankton biomass (blooms) as determined from dissolved oxygen and total chlorophyll *a* measurements. The level of oxygen depletion, the magnitude of daily oxygen excursion and chlorophyll *a* levels within the main basin of Waquoit Bay (north and south) indicate high levels of nutrient enrichment and impaired habitat quality. The effect of nitrogen enrichment is to cause oxygen depletion; however, with increased phytoplankton (or epibenthic algae) production, oxygen levels will rise in daylight to above atmospheric equilibration levels in shallow systems. The clear evidence of oxygen levels above atmospheric equilibration throughout Waquoit Bay and its sub-embayments is further evidence of nitrogen enrichment at a level consistent with habitat degradation.

Overall, the moderate levels of oxygen depletion and moderate chlorophyll-*a* levels with periodic large phytoplankton blooms, and generally low macroalgae accumulations within the northern basin are consistent with the generally productive benthic animal communities. The southern portion of Waquoit Bay is also showing moderate oxygen stress to benthic communities, with a gradient of less oxygen depletion towards the tidal inlet. Eelgrass beds were lost from Waquoit Bay between 1951-1995. This observation is supported by quantitative time-series analysis by Short & Burdick (1996).

Figures 6, 7, and 8 along with Table 2, illustrate the observed habitat impairments for the Waquoit Bay System as discussed in the previous and the subsequent paragraphs.



Symbols: Concentration; high chlorophyll, Eelgrass Loss, Concentration: low dissolved oxygen, s) courtesy of: Tracey Saxby, Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/imagelibrary/). Symbol: Worms courtesy of : Dieter Tracey, Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/imagelibrary/).

Figure 6: Habitat Parameters which show impairment for eastern Waquoit Bay subembayments

Figure 7: Habitat Parameters which show impairment for Waquoit Bay

Western Embayments

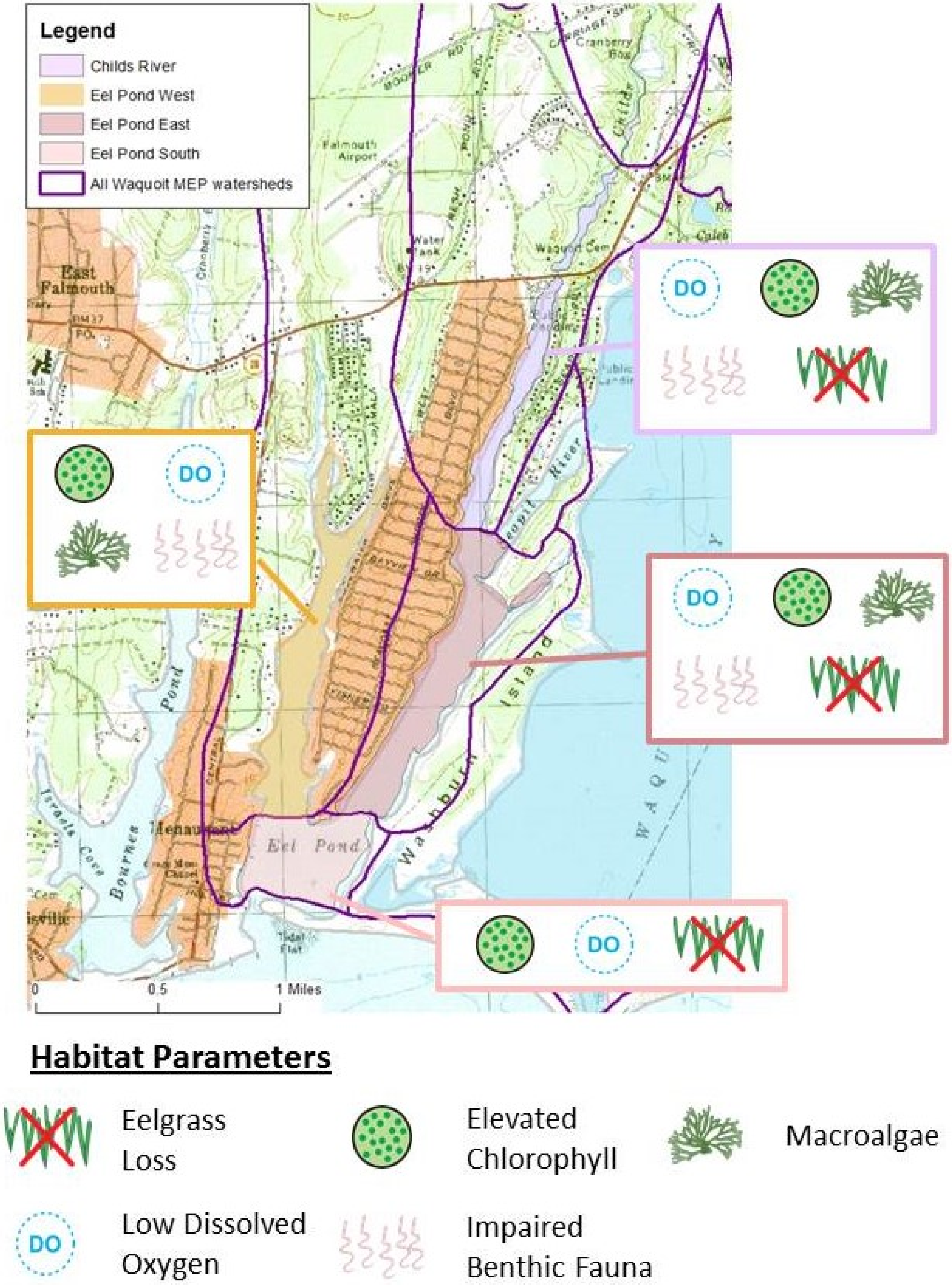
Eel Pond and Childs River, the western sub-embayments to the Waquoit Bay Embayment System, exhibit significant summer time oxygen depletion. The upper reaches within Eel Pond and the main channel of the Childs River have significant and frequent oxygen depletion of bottom waters.

The MEP project measured dissolved oxygen at the single deployment station in the Childs River at <5 mg/L for 38% of the deployment (22.9 days) and <4 mg/L for 24% of deployment. Severe oxygen stress (<3 mg/L) was found for 11% of the deployment. Mashpee Water Quality Monitoring Program (MWQMP) sampling found dissolved oxygen <5 mg/L for 51% and <4 mg/L for 30% of 34 dates. Very high chlorophyll *a* has been documented in the Childs River by the MEP project and MWQMP sampling. The MEP project found a mean chlorophyll *a* of 23.3 ug/L with levels >20 ug/L for 53% of 23-day record and frequently (37%) >25 ug/L during their 23-day deployment. MWQMP sampling in the upper and mid reach of Childs River had a mean chlorophyll *a* of approximately 28 ug/L for 34 sampling dates. Eelgrass has been largely lost since 1995 with no significant coverage since. The Childs River was found to be moderately/significantly impaired with patches of dense *Ulva* and some accumulations of branched forms of drift algae. The benthic community was found to have significant impairment. MEP sampling at two stations found moderate number of individuals, low number of species (11), some stress indicator species (*Capitella*) and a community dominated by organic enrichment species (Crustaceans) with low/moderate diversity (1.9) and Evenness (0.56).

The upper portions of the western branch of Eel Pond clearly present a significant oxygen stress to benthic animals, while the lower Eel Pond basin presently has a lower level of oxygen stress. The MEP project found significant impairment for dissolved oxygen in Eel Pond–west. They found dissolved oxygen was <5 mg/L for 41% of the 74.9-day MEP deployment and <4 mg/L for 22% of deployment at the monitoring station. The MEP project found elevated chlorophyll *a* values at their monitoring station with a mean chlorophyll *a* of 17.4 ug/L, frequently (34%) >20 ug/L of the 72-day deployment record. Their results were mimicked in MWQMP sampling where the upper and mid reach stations had a mean chlorophyll *a* of ~20 ug/L for 34 dates.

The MEP project also found moderate to dense accumulations of branched forms of macroalgae (with Cladophora) and considered the western section of Eel Pond to be significantly/severely impacted. The MEP project found no evidence that this western portion of Eel Pond was supportive of eelgrass. In the three stations sampled for infauna, the MEP found low-moderate number of individuals, low species (8), low diversity (1.5), low numbers of stress indicator species and some areas of depauperate populations (lacking in numbers or variety of species) dominated by organic enrichment species. The benthic community for Eel Pond – west was considered significantly impacted by the MEP project.

The eastern portion of Eel Pond (Eel Pond – east) has been found to be moderately impaired for dissolved oxygen. MWQMP sampling in the upper reach of this waterbody found dissolved oxygen <5 mg/L for 26% of 34 sampling dates and <4 mg/L on 10% of sampling dates. Severe dissolved oxygen depletion was limited with dissolved oxygen <3 mg/L for only 2% of 34 dates. MWQMP has found moderate levels of chlorophyll *a* with a mean of 7.5 ug/L for 34 dates.



Symbols: Concentration; high chlorophyll, Eelgrass Loss, Concentration: low dissolved oxygen, s) courtesy of: Tracey Saxby, Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/imagelibrary/). Symbol: Worms courtesy of : Dieter Tracey, Integration and Application Network, University of Maryland Center for Environmental Science (ian.umces.edu/imagelibrary/).

Figure 8: Habitat Parameters which show impairment for western Waquoit Bay subembayments

Eelgrass beds were lost from Eel Pond- east between 1951-1995, an observation supported by quantitative time-series analysis by Short & Burdick (1996). The MEP project found a moderately impacted benthic community with high numbers of individuals, moderate number of species (18), low numbers of stress indicator species as well as moderate diversity (H'=2.4) and evenness (E=0.57). However, they found a community dominated by amphipod mats and a transitional community dominated by organic enrichment species.

The basin of Eel Pond adjacent the tidal inlet (Eel Pond – south) shows healthy/moderately impacted dissolved oxygen levels (always >4 mg/L, 4-5 mg/L 6% of 85-day record at MEP station), due to the direct influence of the high-quality floodwaters from Vineyard Sound. The measured oxygen conditions were consistent with the general absence of macroalgae and moderate chlorophyll-a levels in this lower basin (<10 ug/L for 82% of 85-day record, MWQMP samples in lower basin had mean 6.6 ug/L of 34 dates). Eelgrass beds were lost from this reach of tidal river between 1951-1995. The MEP project found a healthy benthic community in the lower basin of Eel Pond and the Seapit River with high numbers of individuals, good number of species (23), and moderate diversity (H'=2.6) and evenness (E=0.57).

The lower basin is strongly influenced by the nutrient and organic enriched low oxygen waters entering from the upper tidal reaches during out-flowing ebb tides. However, the high turnover of water in lower Eel Pond reduces its ability to build up nutrients, phytoplankton biomass and organic matter, while the inflow of high-quality floodwaters from Vineyard Sound results in relatively high-water quality for a portion of the flood tide period.

Table 2: Waquoit Bay Embayment System MEP Nutrient Related Habitat Quality (from Table VIII-1a and 1b, Howes et al, 2013)

Health Indicator	**Western Sub-Embayments of the Waquoit Bay System**					
	Waquoit Bay		**Eel Pond**		**Childs River**	**Sage Lot Pond**
	North	**South**	**West**	**East**		
Dissolved Oxygen	MI	MI/SI	SI	MI	SI	H
Chlorophyll *a*	MI/SI	MI	SI	MI	SI	MI
Microalgae	MI	SD	SI/SD	MI	MI/SI	SI
Eelgrass	SI	SI	--	SI	SI	MI
Infaunal Animals	MI	SI	SI	MI	SI	MI/SI
Overall:	**SI**	**SI/SD**	**SI**	**SI**	**SI**	**MI**

Health Indicator	**Eastern Sub-Embayments of the Waquoit Bay System**					
	Upper Quashnet	**Lower Quashnet**	**Hamblin Pond**	**Little River**	**Jehu Pond**	**Great River**
Dissolved Oxygen	SI	SI	MI	MI	SI	MI
Chlorophyll *a*	SD	SI	MI	MI	MI/SI	MI
Microalgae	SD	SD	--[1]	--[1]	--[1]	--[1]
Eelgrass	--[2]	--[2]	MI	MI	MI	MI
Infaunal Animals	SD	SD	MI	H	SI	MI
Overall:	**SD***	**SI/SD***	**MI***	**H/MI***	**SI***	**MI***

MWQMP: Mashpee Water Quality Monitoring Program (2000-2010)
H - Healthy habitat conditions

MI – Moderately Impaired
SI – Significantly Impaired - considerably and appreciably changed from normal conditions
SD – Severely Degraded
--[1] eelgrass loss prior to 1951
--[2] sparse to no accumulation
* These terms are more fully described in MEP report "Site-Specific Nitrogen Thresholds for Southeastern Massachusetts Embayments: Critical Indicators" December 22, 2003 (Howes *et. al*., 2003)

Pollutant of Concern, Sources, and Controllability

In the coastal embayments of the Towns of Mashpee, Falmouth and Sandwich, 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.

Each of the embayments 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 Towns of Mashpee, Falmouth and Sandwich, 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 (Howes *et. al*, 2013).

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 a large percentage of its natural habitat in these sub-embayments. 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.

The level of "controllability" of each source, however, varies widely. A brief overview of the sources of nitrogen and their contributions are detailed in Table 3. Cost/benefit analyses will have to be conducted on possible N loading reduction methodologies in order to select the optimal control strategies, priorities, and schedules.

As is illustrated by Figure 9a most of the present watershed nitrogen load to the Waquoit Bay system is from on-site subsurface wastewater disposal systems (septic systems), with considerably less N originating from natural background sources, runoff, fertilizers, wastewater treatment facilities, and atmospheric deposition. The watershed nitrogen loading that is considered controllable affecting this system originates predominately from on-site subsurface wastewater disposal systems (septic systems, 75%), impervious surfaces (13%) and fertilizers (12%) and two wastewater treatment facilities (<0.5%) (Figure 9b).

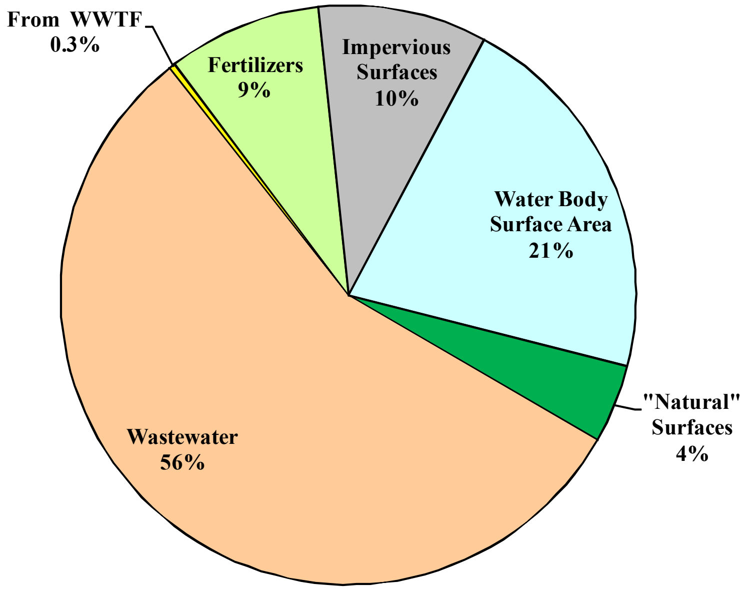


Figure 9a: Percent Contributions of All Watershed Nitrogen Sources to the Waquoit Bay Embayment System

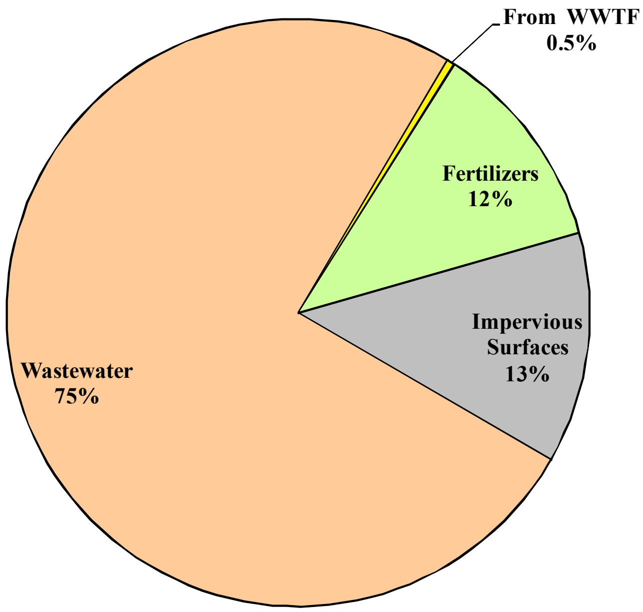


Figure 9b: Percent Contributions of Controllable Watershed Nitrogen Sources to the Waquoit Bay Embayment System

Table 3: Sources of Nitrogen and their Controllability

Nitrogen Source	Degree of Controllability at Local Level	Reasoning
Agricultural fertilizer and animal wastes	Moderate	These nitrogen loadings can be controlled through appropriate agricultural Best Management Practices (BMPs).
Atmospheric deposition to the estuary surface	Low	It is only through region- and nation-wide air pollution control initiatives that significant reductions are feasible. Local control although helpful is not adequate.
Atmospheric deposition to natural surfaces (forests, fields, freshwater bodies) in the watershed	Low	Atmospheric deposition (loadings) to these areas cannot adequately be controlled locally. However, the N from these sources might be subjected to enhanced natural attenuation as it moves toward the estuary.
Fertilizer	Moderate	Lawn and golf course fertilizer and related N loadings can be reduced through BMPs, bylaws and public education.
Septic system	High	Sources of N 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 N-reducing on-site wastewater treatment systems.
Sediment	Low	N loadings are not feasibly controlled on a large scale by such measures as dredging. 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. In addition, increased dissolved oxygen will help keep N from fluxing.
Stormwater runoff from impervious surfaces	Moderate	This nitrogen source can be controlled by BMPs, bylaws and stormwater infrastructure improvements and public education. Stormwater NPDES permit requirements help control stormwater related N loadings in designated communities.
Wastewater treatment facility (WWTF)	High	Wastewater treatment facilities as point sources of pollution to surface water are permitted under the National Pollution Discharge Elimination System. Treated wastewater effluent discharged to groundwater disposal systems are permitted by MassDEP. There is a high degree of regulatory certainty that within the limits of technology, nutrient sources at these facilities can be controlled.

Description of the Applicable Water Quality Standards

The water quality classification of Waquoit Bay and all estuarine embayments in this TMDL are Class SA and fresh water segments are Class B. Water quality standards of particular interest to the issues of cultural eutrophication are dissolved oxygen, nutrients, aesthetics, and 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. The narrative standards for nutrients (nitrogen and phosphorus) for waters of the Commonwealth are such that "all surface waters shall be free of nutrients in concentrations that would cause or contribute to impairment of existing or designated uses and shall not exceed site specific criteria developed in a TMDL or otherwise, established by the department" (MassDEP 2007). A more thorough explanation of applicable standards can be found in Appendix A.

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 Nutrient Criteria Technical Guidance Manual for Estuarine and Coastal Marine Waters (EPA-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.

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 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) Restore and preserve benthic communities;
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.

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 numerous embayments thus far 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. 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. It should be noted that this approach includes high-order, watershed and sub-watershed scale modeling necessary to develop critical nitrogen targets for each major sub-embayment. The models, data and assumptions used in this process are specifically intended for the purposes stated in the MEP Technical Report, upon which this TMDL is based. As such, the Linked Model process does not contain the type of data or level and scale of analysis necessary to predict the fate and transport of nitrogen through groundwater from specific sources. In addition, any determinations related to direct and immediate hydrologic connection to surface waters are beyond the scope of the MEP’s Linked Model process.

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-2 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
    - Chlorophyll *a* record
    - Eelgrass and Infaunal survey

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 stations or sampling locations within the embayment system located close to the inland-most reach or reaches which typically has/have 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 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 concentration

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

- the present attenuated 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 (for dissolved oxygen, nutrients) by reducing the N concentration (and thus the N 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:

Nitrogen concentrations in the embayments

1. Observed "present" conditions:

Table 4 presents the average concentrations of N measured in the sub-embayments from 2002 through 2010. Concentrations of N are the highest in the Upper Childs River (1.190 mg/L). Nitrogen in the other sub-embayment's ranges in concentration from 0.392 to 0.888 mg/L, resulting in overall ecological habitat quality ranging from good/fair to severely degraded. The individual yearly means and standard deviations of the averages are presented in Appendix B.

Table 4: Measured Nitrogen Concentrations for the Waquoit Bay System and Target Concentrations at Sentinel Stations. Data collected from 2002 through 2010.

Subembayment	Station ID	Mean[1]	standard deviation (all data)	number samples	Target Threshold N Concentrations (mg/L)[2]
Upper Waquoit Bay	WB12	0.469	0.085	44	0.38[4]
Lower Waquoit Bay	WB13	0.392	0.057	45	
Seapit River WB	WB11	0.528	0.078	33	
Quashnet River (freshwater)	WB06	0.516	0.117	29	
Upper Quashnet River	WB07	0.632	0.196	24	
Mid Quashnet River	WB08	0.791	0.242	30	0.50[5]
Lower Quashnet River	WB09	0.633	0.127	32	
Red Brook (freshwater)	WB05	0.561	0.086	25	
Hamblin Pond	WB04	0.517	0.079	37	0.38[3,4]
Hamblin Pond Drain	WB10	0.59	0.126	34	
Jehu Pond	WB01	0.581	0.096	36	0.446[3,4]
Upper Great River	WB02	0.585	0.125	33	0.446[3,4]
Great/Little River	WB03	0.535	0.109	34	
Upper Childs River	CR01	1.190	0.232	19	
Mid Childs River	CR02	0.888	0.337	23	0.374[4]
Lower Childs River	CR03	0.474	0.066	20	
Upper Eel River	ER01	0.742	0.132	20	</=0.50[5]
Lower Eel River	ER02	0.622	0.138	21	

Subembayment	Station ID	Mean[1]	standard deviation (all data)	number samples	Target Threshold N Concentrations (mg/L)[2]
Eel Pond	ER03	0.404	0.059	19	
Vineyard Sound	VS	0.28	0.065	196	

[1] Mean values are calculated as the average of the separate yearly means.
[2] From Howes et al, 2013, Table VIII-5, unless noted. Sentinel stations shown in Figure 10.
[3] From Howes et al, 2005.
[4] Primary target for eelgrass habitat restoration.
[5] Secondary target for benthic infauna habitat restoration.

2. Modeled site-specific target threshold N concentration

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. This is called the *target threshold nitrogen concentration*. 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.

Threshold N levels for each of the sub-embayment systems in this study were developed to restore or maintain SA waters or high habitat quality. In these systems, high habitat quality was defined as supportive of eelgrass and diverse benthic animal communities. Dissolved oxygen and chlorophyll *a* were also considered in the assessment.

The threshold N levels for these Waquoit Bay sub-embayments were determined as follows:

The approach for determining nitrogen loading rates, which will maintain acceptable habitat quality throughout the embayment system, is to first identify a sentinel location within the embayment or sub-embayment and second, to determine the nitrogen concentration within the water column which will restore that location to the desired habitat quality. The sentinel location is selected such that the restoration of that one site will necessarily bring the other regions of the system to acceptable habitat quality levels. Once the sentinel site(s) and its target nitrogen level are determined, the Linked Watershed-Embayment Model is used to sequentially adjust nitrogen loads until the targeted nitrogen concentration is achieved. Given the complex configuration and hydrodynamics of the Waquoit Bay Embayment System, multiple nitrogen threshold locations were selected as to ensure an accurate determination of estuarine response to reductions in watershed nitrogen loading and/or enhanced tidal flushing.

Basins within the Waquoit Bay Embayment System with historic eelgrass coverage include, Waquoit Bay (main basin, Great River, Little River, Jehu Pond, Sage Lot Pond, Childs River, Eel Pond- East and Eel Pond – South). With the exception of Sage Lot Pond and Jehu Pond substantively all eelgrass has been lost from the Waquoit Bay Embayment System. Each of the basins with well documented historic eelgrass coverage within this system which no longer support eelgrass coverage are classified as significantly impaired relative to eelgrass habitat. Since eelgrass is more sensitive to nitrogen enrichment than benthic animal habitat, restoration of eelgrass habitat in these basins is anticipated to also restore impairments to benthic habitat as well.

Within the main basin of **Waquoit Bay**, a sentinel station was selected at the long-term monitoring location (WB12), with a target N concentration of **0.38 mg/L**. The restoration target was established for eelgrass habitat within the northern and southern portions of the basin (Figure 10). Similarly, within the **Childs River** the long term monitoring within the main channel near the upper extent of the historic eelgrass coverage was selected (CR02) with a target N concentration of **0.374 mg/L**. Meeting the nitrogen target at both these stations will necessarily result in lower total nitrogen levels in the down gradient, Eel Pond, (east branch and lower basin) to restore eelgrass within these areas as well as restoring eelgrass habitat in the southern, tidal reaches of Waquoit Bay..

Figure 10 Estuarine Water Quality Monitoring Stations. Sentinel Stations as noted in Table 4. (excerpted Howes *et. al*, 2013, pg. 117)

Meeting the nitrogen threshold in upper Waquoit Bay will also lower nitrogen related impairments in Sage Lot Pond, which is presently supporting moderately impaired eelgrass habitat. Sage Lot Pond is presently just over its nitrogen threshold, and only a moderate reduction in nitrogen levels is required to achieve restoration. Sage Lot Pond exchanges tidal waters with the lower portion of Waquoit Bay, therefore as nitrogen levels are reduced in the main basin, Sage Lot Pond levels will decline as well. Tidal marshes, such as Sage Lot Pond, typically are more organically enriched (lower dissolved oxygen and higher N) while still maintaining habitat functions.

The target nitrogen concentration (tidally averaged total N) for restoration of eelgrass at the sentinel locations within Waquoit Bay and Child River basins is based upon comparison to other local embayments of similar depths and structure under MEP analysis.

Eelgrass beds still exist within Hyannis Harbor at tidally averaged nitrogen levels of 0.37 mg/L, similar to that in the Oyster River (Chatham). More stringent nitrogen thresholds (0.35 mg/L) have been determined for the deeper waters of Phinneys Harbor and West Falmouth Harbor estuaries where detailed eelgrass/nitrogen analysis was available. These site-specific data indicate that the threshold for eelgrass in this system is between 0.370 and 0.393 (or 0.385) mg/L, tidally averaged total N.

Since the western basin of Eel Pond has not historically supported eelgrass beds, but presently has significantly impaired benthic animal habitat the target for restoration is benthic infauna habitat. Benthic animals are more tolerant of nutrient and organic matter enrichment than eelgrass, which requires clear waters and high oxygen levels. The observed impairments throughout the western basin of Eel Pond are consistent with observations by the MEP Technical Team in other estuaries along Nantucket Sound (e.g. Perch Pond, Bournes Pond, Popponesset Bay) where levels N levels <0.5 mg/L were found to be supportive of healthy infaunal habitat and where moderately impaired habitat was found at N levels ~0.6 mg/L. Similarly, moderate impairment was also observed at N levels (0.535-0.600 mg/L) within the Wareham River Estuary, while the Centerville River system showed moderate impairment at tidally averaged N levels of 0.526 mg/L in Scudder Bay and at 0.543 mg/L in the deep middle reach of the Centerville River. Based upon these observations, the MEP Technical Team concluded that an upper limit of </=0.50 mg/L tidally averaged N at the threshold station (ER01) would result in healthy infaunal habitat throughout the western branch of Eel Pond (Howes *et. al* 2013 pg. 193).

The Quashnet River Estuary operates independent from the Hamblin Pond and Jehu Pond Estuaries, except that they share common source waters from Waquoit Bay. The sentinel system within the Quashnet River Estuary was set within the upper/mid basin (Figure 10, approximately the location of WB08). Since there is no historical evidence that the Quashnet River Estuary supported eelgrass, the threshold nitrogen concentration of 0.5 mg/L is set based upon restoring benthic habitat at the sentinel stations. Achieving the nitrogen threshold at station WB08 will also improve benthic habitat in the lower basin. These values are consistent with the infaunal guidance levels within the Popponesset Bay sub-embayments of 0.5 to 0.4 mg/L (0.5 mg/L) being the upper threshold value). Based upon these data a conservative estimate for the infaunal threshold for the **Quashnet River Estuary** is **0.50 mg/L** (Howes *et. al* 2013 pg. 193).

Within the Hamblin Pond/Little River and Jehu Pond/Great River Estuaries the sentinel locations were placed within the pond basins. The target nitrogen threshold focuses on eelgrass restoration of these systems. Given the nitrogen gradients, with the ponds having the highest nitrogen levels within their respective estuarine sub-embayment, achieving the nitrogen target in the ponds will necessarily result in high quality habitat in the down-gradient reaches.

To refine the nitrogen threshold for Jehu and Hamblin Ponds, modeling was conducted. The goal of this effort was to reconcile nitrogen levels to historical shifts in eelgrass distribution. The concept was to use conservative estimates of nitrogen loads and concentrations to estimate nitrogen levels prior to the eelgrass loss in the main bay and ponds. Achieving the nitrogen threshold concentration at the sentinel stations, will result in the restoration of dissolved oxygen and chlorophyll a to levels supportive of eelgrass and benthic infaunal habitats.

Based upon the modeling it appears that **Jehu Pond** could support eelgrass at a nitrogen threshold of **0.446 mg/L**. This level for Jehu Pond is also consistent with the pattern and timing of eelgrass loss throughout the Waquoit Bay System. Although Hamblin Pond is similar to Jehu Pond in gross structure, it has very different loading and attenuation characteristics. The result is that the structure of the system produces much lower nitrogen levels therefore a threshold of **0.38 mg/L** was selected for **Hamblin Pond** to allow for uncertainties (Howes *et. al* 2013 pg. 194).

It will not be possible to achieve the target nitrogen levels for the Quashnet River, Hamblin Pond/Little River or Jehu Pond/Great River Estuary without lowering the nitrogen level within the main basin of Waquoit Bay. At present the flooding waters from Waquoit Bay are sufficiently nitrogen enriched that even modest nitrogen loads from the watersheds to these estuaries exceed nitrogen targets. The target threshold concentration for the Waquoit Bay main basin is set at 0.38 mg/L, lower than the targets in the upper embayments due to the mixing of the tidal waters between the main basin and the sub-embayments.

Nitrogen Loadings to the Embayment

1) Present loading rates:

In the Waquoit Bay System overall, the highest N loading from controllable sources is from on-site wastewater treatment systems, which is almost always the highest N loading source in other coastal embayments as well. The MEP Technical Report calculates that septic systems account for 64 kg/day N, or 75% of the total controllable load. The total watershed N loading (excluding atmospheric deposition and benthic flux) is approximately 91 kg/day. Nitrogen loading from the nutrient-rich sediments (referred to as benthic flux) is significant in these sub-embayments. 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 watershed load should reduce the benthic flux over time. A breakdown of attenuated N loading, by source, is presented in Table 5. This table is based on data from Table ES 1 of the MEP Technical Report for this embayment system (Howes *et. al*, 2013).

Table 5: Present Attenuated Nitrogen Loading to the Waquoit Bay System (excerpted from Howes et. al, 2013)

Subembayment	MEP Component Watersheds *	Present Land Use Load [1] (kg/day)	Present Septic System Load (kg/day)	Present WWTF Load [2] (kg/day)	Present Total Watershed Load [3] (kg/day)	Direct Atmospheric Deposition [4] (kg/day)	Present Net Benthic Flux (kg/day)
Groundwater sources							
Waquoit Bay	8, 9, 12	0.690	1.397	-	2.088	11.956	-69.126
Childs River- upper	7, 5*	2.090	9.929	-	12.019	0.455	-7.437
Eel Pond- east branch	10	0.482	1.688	-	2.170	1.011	26.004
Eel Pond- south basin	11	0.066	0.458	-	0.523	0.663	-5.65
Eel Pond- west branch	1, 2*, 40*, 41*	3.789	12.548	-	16.337	0.890	-4.383
Quashnet River	31, 32, 30	0.868	1.904	-	2.773	0.252	11.996
Hamblin Pond	26, 27, 28, 24, 25	0.953	3.427	-	4.381	1.529	7.890
Little River	29	0.211	0.885	-	1.096	0.156	3.439
Jehu Pond	17, 18	1.025	2.888	-	3.912	0.674	9.854
Great River	19, 20, 21	0.997	2.674	-	3.671	1.307	19.679
Sage Lot Pond	13, 14, 15, 16	1.619	1.132	-	2.753	0.471	-3.086
Freshwater sources							
Childs River	6, 3, 2*, 36*, 37*, 38*, 39*, 40*, 41*, 42*, 43*, 44*, 45*	2.485	8.134	0.003	10.622	-	-
Quashnet River	33, 34, 35, 47, 48, *36, *37 *38, *39, *40, *41, *42, *43, *44, *45	9.641	10.504	0.362	20.507	-	-
Red Brook	22, 23	1.438	6.575	-	8.014	-	-
Total		26.354	64.143	0.365	90.866	19.364	-10.821

1-composed of non-wastewater loads, e.g. fertilizer, runoff, natural surfaces and atmospheric deposition to lakes
2-existing attenuated wastewater treatment facility discharges to groundwater
3-composed of combined natural background, fertilizer, runoff, and septic system loadings (the sum of land use, septic, and WWTF loading)
4-atmospheric deposition to embayment surface only. Atmospheric loads to surface water inputs are included with their respective watershed load.
* Partial contribution from these component watersheds, see Figure 1 for watersheds.

As previously indicated, the present N loadings to the Waquoit 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 threshold N concentrations.

2) Nitrogen load reductions necessary for meeting the site-specific target threshold N concentration:

The nitrogen thresholds developed by SMAST (Section VIII.2 in the MEP Technical Report) and summarized above was used to determine the amount of total nitrogen mass loading reduction required for restoration of eelgrass and infaunal habitats in the Waquoit Bay embayment system. Tidally averaged total nitrogen concentrations were used to calibrate the water quality model (Section VI in the MEP Technical Report). Modeled watershed nitrogen loads were sequentially lowered until the nitrogen levels reached the threshold level at the selected sentinel stations. It is important to note that load reductions can be produced by reduction of any or all sources of N and/or by increasing the natural attenuation of nitrogen within the freshwater systems to the embayment. The load reductions presented here represent only one of a suite of potential reduction approaches that need to be evaluated by the community.

In the scenario presented, the percentage reductions in N loadings to meet threshold concentrations range from approximately 34% in the freshwater portion of Quashnet River to approximately 81% in the Little River. Table 6 includes the present and target threshold watershed N loadings to Waquoit Bay embayment system and the percentage reduction necessary to meet the target threshold N concentration at the sentinel stations (from Table ES-2 of the MEP Technical Report). These values represent only one of a suite of potential reduction approaches that need to be evaluated by the towns. The presentation is to establish the general degree and spatial pattern of reduction that will be required for restoration of this N impaired embayment. Other alternatives may also achieve the desired target threshold N concentration as well and can be explored using the MEP modeling approach. The towns should take any reasonable actions to reduce the controllable N sources.

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 Waquoit Bay embayment system are aimed at determining the loads that would correspond to specific N concentrations determined to be protective of the water quality and ecosystems. Bioavailable nutrients - such as nitrogen - in point and non-point discharges can stimulate algal growth, which then die and are eaten by bacteria, depleting oxygen in the water through the process of decomposition. Reducing the bioavailability of nitrogen in the estuarine system through the implementation of this TMDL will result in less algal growth, which will ensure chlorophyll-a levels are reduced and dissolved oxygen levels increase.

Table 6: Present Attenuated Watershed Nitrogen Loading Rates, Calculated Loading Rates that are Necessary to Achieve Target Threshold Nitrogen Concentrations, and the Percent Reductions of the Existing Loads Necessary to Achieve the Target Threshold Loading (excerpted from Howes *et. al* 2013)

Subembayment	Present Controllable Watershed Load[1] (kg/day)	Target Threshold Watershed Load[2] (kg/day)	% Reductions Needed to Achieve Target Threshold Loads
Groundwater sources			
Waquoit Bay	2.088	2.088	0.0%
Childs River- upper	12.019	4.076	-66.1%
Eel Pond- east branch	2.17	0.82	-62.2%
Eel Pond- south basin	0.523	0.523	0.0%
Eel Pond- west branch	16.337	8.808	-46.1%
Quashnet River	2.773	1.497	-46.0%
Hamblin Pond	4.381	0.953	-78.2%
Little River	1.096	0.211	-80.7%
Jehu Pond	3.912	1.025	-73.8%
Great River	3.671	0.997	-72.8%
Sage Lot Pond	2.753	1.622	-41.1%
Freshwater sources			
Childs River	10.622	4.115	-61.3%
Quashnet River	20.507	13.469	-34.3%
Red Brook	8.014	2.096	-73.8%
Total	90.866	42.3	-53.4%

[1] Composed of combined fertilizer, runoff, WWTP effluent, and septic system loadings.
[2] Target threshold watershed load is the combined load from the sub-watersheds using one scenario that will meet the embayment threshold N concentrations identified above.

The development of a TMDL requires detailed analyses and mathematical modeling of land use, nutrient loads, water quality indicators, and hydrodynamic variables (including residence time), for each waterbody system. 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 the loading estimates but is not quantified or presented separately. Background loading was calculated on the assumption that the entire watershed is forested, with no anthropogenic sources of N. It is accounted for in this TMDL but not defined as a separate component. Readers are referred to Table ES-1 of the MEP Technical Report for estimated loading due to natural conditions.

Wasteload Allocations

Wasteload allocations identify the portion of the loading capacity allocated to existing and future point sources of wastewater. In the Waquoit Bay Embayment system there are no permitted surface water discharges with the exception of stormwater. A TMDL may establish a specific WLA for an identified source or, as in the case of stormwater, may establish an aggregate WLA that applies to numerous sources. EPA interprets 40 CFR 130.2(h) to require that allocations for NPDES regulated discharges of stormwater be included in the waste load component of the TMDL. In this embayment system this includes runoff from impervious surfaces.

There are two small wastewater treatment facilities that discharge to groundwater in the Waquoit Bay embayment system, but they are not considered point sources under EPA definition. These facilities (Mashpee Junior/Senior High School and Southport Condominiums) are located in the Quashnet River sub-watershed and are required to denitrify as part of their groundwater discharge permit. Both permits require effluent discharge less than 10 mg/L N to the groundwater.

For purposes of the Waquoit Bay embayment system TMDLs, MassDEP considered the nitrogen load reductions from regulated Municipal Separate Storm Sewer Systems (MS4s) sources necessary to meet the target nitrogen concentrations. In estimating the nitrogen loadings from regulated stormwater sources, MassDEP considered that most stormwater runoff in the MS4 communities is not discharged directly into surface waters, but, rather, percolates into the ground. The geology on Cape Cod consists primarily of glacial outwash sands and gravels, and water moves rapidly through this type of soil profile. A systematic survey of stormwater conveyances on Cape Cod had not been conducted prior to or during the MEP technical study used in the development of this TMDL. Nevertheless, most catch basins on Cape Cod are known to MassDEP to have been designed as leaching catch basins in light of the permeable overburden. MassDEP, therefore, recognized that most stormwater that enters a catch basin in the regulated area will percolate into the local groundwater table rather than directly discharge to a surface waterbody.

As described in the Methodology Section (above), the Linked Model accounts for storm water loadings and groundwater loading in one aggregate allocation as a non-point source. However, MassDEP also considered that some stormwater collected in the regulated area is discharged directly to surface waters through outfalls. In the absence of specific data or other information to accurately quantify stormwater discharged directly to surface waters, MassDEP assumed that all impervious surfaces within 200 feet of the shoreline, as calculated from MassGIS data layers, would discharge directly to surface waters, whether or not it in fact did so. MassDEP selected this approach because it considered it unlikely that any stormwater collected farther than 200 ft. from the shoreline would be directly discharged into surface waters. Although the 200-foot approach provided a gross estimate, MassDEP considered it a reasonable and conservative approach given the lack of pertinent data and information about stormwater collection systems on Cape Cod.

The waste load allocation for the impervious surfaces within 200 feet of the embayments is estimated to be approximately 1.0% (0.51 kg/day) as compared to the overall estuarine watershed nitrogen load (53.10 kg/day) to the embayments (Appendix C). The waste load allocation for individual sub-embayments ranged from 0.0-3.7% of the total load. 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. This load is obviously negligible when compared to other sources.

Load Allocations

Load allocations identify the portion of loading capacity allocated to existing and future nonpoint sources. In the case of the Waquoit Bay System sub-embayments studied, the nonpoint source loadings are primarily from on-site subsurface wastewater disposal systems, with an attenuated nitrogen load of 64.1 kg/day N. Additional N sources include stormwater runoff (except from impervious cover within 200 feet of the waterbody which is defined above as part of the waste load), fertilizers, and two small WWTF groundwater discharges. The total attenuated nitrogen load from these sources is approximately 26.7 kg/day N. In addition, there are nonpoint sources of N that are not feasibly controllable from nutrient-rich sediments (benthic flux), atmospheric deposition, and natural background.

Stormwater that is subject to the EPA Phase II Program is 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. As discussed above, even though there are measureable directly connected impervious areas in these systems, the wasteload allocation for stormwater was determined to be insignificant when compared to the overall controllable N load. Accordingly, this TMDL accounts for stormwater loadings and groundwater loadings in one aggregate allocation as a non-point source, thus combining the assessments of wastewater and stormwater for the purpose of developing control strategies. Continued Phase II Program implementation in the embayment system towns, new studies and possibly further modeling will identify what portion of the stormwater load may be controllable through Best Management Practices (BMPs).

The total attenuated nitrogen load of the two WWTFs is about 0.365 kg/day of nitrogen discharged into the groundwater. This represents less than 1% of the nitrogen load into the Waquoit Bay System sub-embayments studied. This small percentage of N load is due to the fact that the volume of wastewater effluent discharged by these facilities is small and the groundwater discharge permits for these facilities have low nitrogen limits.

The sediment loading rates incorporated into the TMDL are different than the existing benthic input listed in Table 5 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 N (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: $PON\ projected = (R_{load})\ (D_{PON}) + PON_{present\ offshore}$

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

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

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

Benthic loading is affected by the change in watershed load. The benthic flux modeled for the sub-embayments of the Waquoit Bay System is reduced from existing conditions based on the load reduction from controllable sources. The benthic flux in each sub-embayment was reduced (toward zero) based on the reduction of N in the watershed load. Negative fluxes were set to zero. This conservative approach was used and is considered part of the margin of safety in the TMDL.

The loadings from atmospheric sources incorporated into the TMDL, are the same rates presently occurring, because, as discussed above, local control of atmospheric loadings is not considered feasible.

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(C),40C.G.R. para 130.7(C) (1)]. The MOS must be designed to ensure that any uncertainties in the data or calculations used to link pollutant sources to water quality impairment modeling will be accounted for in the TMDL and ensure protection of the beneficial uses. 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. An explicit MOS quantifies an allocation amount separate from other Load and Wasteload Allocations. An explicit MOS can incorporate reserve capacity for future unknowns, such as population growth or effects of climate change on water quality. An implicit MOS is not specifically quantified but consists of statements of the conservative assumptions used in the analysis. The MOS for the Waquoit Bay embayment system TMDLs is implicit. MassDEP used conservative assumptions to develop numeric model applications that account for the MOS. These assumptions are described below, and they account for all sources of uncertainty, including the potential impacts of changes in climate.

While the general vulnerabilities of coastal areas to climate change can be identified, specific impacts and effects of changing estuarine conditions are not well known at this time (http://bit.ly/MAClimateAdaptation). Because the science is not yet available, MassDEP is unable to analyze climate change impacts on streamflow, precipitation, and nutrient loading with any degree of certainty for TMDL development. In light of these uncertainties and informational gaps, MassDEP has opted to address all sources of uncertainty through an implicit MOS. MassDEP does not believe that an explicit MOS approach is appropriate under the circumstances or will provide a more protective or accurate MOS than the implicit MOS approach, as the available data simply does not lend itself to characterizing and estimating loadings to derive numeric allocations within confidence limits. Although the implicit MOS approach does not expressly set aside a specific portion of the load to account for potential impacts of climate change, MassDEP has no basis to conclude that the conservative assumptions that were used to develop the numeric model applications are insufficient to account for the lack of knowledge regarding climate change.

Conservative assumptions that support an implicit MOS:

1. Use of conservative data in the linked model

The watershed N model provides conservative estimates of N loads to the embayment. 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. In this context, “direct groundwater discharge” refers to the portion of fresh water that enters an estuary as groundwater seepage into the estuary itself, as opposed to the portion of fresh water that enters as surface water inflow from streams, which receive much of their water from groundwater flow. Nitrogen from the upper watershed regions, which travels through ponds or wetlands, almost always enters the embayment via stream flow, and 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%. For the water quality model, it was possible to conduct a quantitative assessment of the model results as fitted to a baseline dataset - computed root mean squared (RMS) error is less than 0.01 mg/l, which demonstrates a good fit between modeled and measured data for this system (Howes *et. al* 2013, pg. 122). 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 is derived from measured N concentrations, pond delineations and pond bathymetry. There are eight freshwater ponds within the Waquoit Bay delineated watershed. Only Ashumet Pond had bathymetric data and sufficient pond-wide sampling to assign a pond-specific nitrogen attenuation rate and this data supports the use of a 50% attenuation rate. As such, a reasonable pond-specific nitrogen attenuation rate could not be developed for the other fresh ponds within the Waquoit Bay system. All ponds within the delineated subwatersheds were assigned a 50% nitrogen attenuation rate. Nitrogen attenuation in freshwater ponds has generally been determined by the MEP analysis to be at least 50%, so the watershed model assigns a conservative attenuation of 50% to all nitrogen from freshwater pond watersheds unless there is sufficient information to develop a pond-specific attenuation rate to incorporate into the loading analysis.

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 N/L, 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.

Finally, the predicted reductions in benthic regeneration of N are most likely underestimates, i.e. conservative. The reduction is based solely on a reduced deposition of PON, due to lower primary production rates under the reduced N loading in these systems. As the N loading decreases and organic inputs are reduced, it is likely that rates of coupled remineralization-nitrification, denitrification and sediment oxidation will increase. It was also conservatively assumed that the present benthic flux uptake (negative flux) measured in the several sub-watersheds does not exist under future loading conditions and as such was set to zero for purposes of the TMDL.

Benthic regeneration of N is dependent upon the amount of PON deposited to the sediments and the percentage that is regenerated to the water column versus being denitrified or buried. The regeneration rate projected under reduced N loading conditions was based upon two assumptions (1) PON in the embayment in excess of that of inflowing tidal water (boundary condition) results from production supported by watershed N inputs and (2) Presently enhanced production will decrease in proportion to the reduction in the sum of watershed N inputs and direct atmospheric N input. The latter condition would result in equal embayment versus boundary condition production and PON levels if watershed N loading and direct atmospheric deposition could be reduced to zero (an impossibility of course). This proportional reduction assumes that the proportion of remineralized N will be the same as under present conditions, which is almost certainly an underestimate. As a result, future N regeneration rates are overestimated which adds to the margin of safety.

Finally, decreases in air deposition through continuing air pollution control efforts are unaccounted for this TMDL and provide another component of the margin of safety.

2. Conservative sentinel station/target threshold nitrogen concentration

Conservatism was used in the selection of the sentinel stations and target threshold N concentrations. The 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 concentration. Meeting the target threshold N concentrations at the sentinel stations 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 and therefore this approach is conservative.

Finally, the linked model accounted for all stormwater loadings and groundwater loadings in one aggregate allocation as a nonpoint source and this aggregate load is accounted for in the load allocation. The method of calculating the WLA in the TMDL for impervious cover within the 200-foot buffer area of the waterbody was conservative as it did not disaggregate this negligible load from the modeled stormwater LA, hence this approach further enhances the margin of safety.

In addition to the margin of safety within the context of setting the N threshold levels as described above, a programmatic margin of safety also derives from continued monitoring of these embayments 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 TMDLs for the waterbody segments are based on the most critical time period, i.e. the summer growing season, the TMDLs are 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, do not lend themselves to intra-annual manipulation since the majority of the N is from non-point sources. Thus, calculating annual loads is most appropriate, since it is difficult to control non-point sources of N on a seasonal basis and N sources can take considerable time to migrate to impacted waters.

TMDL Values for Waquoit Bay System

As outlined above, the total maximum daily loadings of N that would provide for the restoration and protection of each sub-embayment were calculated by considering all sources of N grouped by natural background, point sources, and non-point sources. A more meaningful way of presenting the loadings data, from an implementation perspective, is presented in Table 7 and Appendix D. In this table the N loadings from the atmosphere and sediments are listed separately from the target watershed threshold loads, which are composed of natural background N along with locally controllable N from the WWTFs, on-site subsurface wastewater disposal systems, stormwater runoff, and fertilizers.

Table 7: The Total Maximum Daily Loads (TMDL) for the Waquoit Bay System sub-embayments.

Subembayment	Present Watershed Load (kg/day)	Target Watershed Load[1] (kg/day)	Atmospheric Deposition (kg/day)	Benthic Flux[2] (kg/day)	TMDL[3] (kg/day)	Percent Reductions
Groundwater						
Waquoit Bay	2.09	2.09	11.96	0.00	14.04	0.0
Childs River - upper	12.02	4.08	0.46	0.00	4.53	-66.1
Eel Pond - east	2.17	0.82	1.01	19.48	21.31	-62.2
Eel Pond - south	0.52	0.52	0.66	0.00	1.19	0.0
Eel Pond - west	16.34	8.81	0.89	0.00	9.70	-46.1
Quashnet River	2.77	1.50	0.25	9.50	11.25	-46.0
Hamblin Pond	4.38	0.95	1.53	5.71	8.19	-78.2
Little River	1.10	0.21	0.16	2.55	2.92	-80.7
Jehu Pond	3.91	1.03	0.67	6.90	8.60	-73.8
Great River	3.67	1.00	1.31	14.22	16.53	-72.8
Sage Lot Pond	2.75	1.62	0.47	0.00	2.09	-41.1
Freshwater						
Childs River[4]	10.62	4.12			4.12	-61.3
Quashnet River[4]	20.51	13.47			13.47	-34.3
Red Brook[4]	8.01	2.10			2.10	-73.8
Waquoit Bay System Total	90.87	42.30	19.36	58.36	120.02	-53.4

1- Target threshold watershed load is the load from the watershed needed to meet the embayment threshold concentrations identified in Table 4.
2 -Projected sediment N loadings obtained by reducing the present loading rates (Table 5) proportional to proposed watershed load reductions and factoring in the existing and projected future concentrations of PON. (Negative fluxes set to zero.)

3 -Sum of target threshold watershed load, atmospheric deposition load, and benthic flux load.
4 -Protective TMDLs have been assigned due to hydraulic connection to impaired embayments

In the case of the Waquoit Bay embayment system, the TMDLs were calculated by projecting reductions in locally controllable on-site subsurface wastewater disposal systems, stormwater runoff, and fertilizer sources. 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. It must be demonstrated however, that any alternative implementation strategies will be protective of the entire embayment system. Once again, the goal of this TMDL is to achieve the identified target threshold N concentration at the identified sentinel stations.

Implementation Plans

The critical element of this TMDL process is achieving the sub-embayment specific target threshold N concentrations presented in Table 4 above, that are necessary for the restoration and protection of water quality, benthic invertebrate habitat and eelgrass habitat within the Waquoit Bay subembayments study area. In order to achieve those target concentrations, N loading rates must be reduced throughout the Waquoit Bay System. Table 7, above, lists target watershed threshold loads for each sub-embayment studied.

Septic Systems

Table VIII-2 of the MEP Technical Report (Table 8 below) 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 these Waquoit Bay sub-embayments, 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.

The above modeling results provide one scenario of achieving the threshold levels at the sentinel sites within the embayment system. This example does not represent the only method for achieving this goal. The Towns are encouraged to evaluate other load reduction scenarios and take any reasonable steps to reduce the controllable N sources 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 the overall Waquoit Bay System, and that none of the sub-embayments will be negatively impacted. To this end, additional linked model runs can be performed by the MEP to assist the planning efforts of the Towns in achieving target N loads that will result in the desired threshold concentrations.

Because the vast majority of controllable N load is from individual septic systems for private residences, the Comprehensive Wastewater Management Plan (CWMP) should assess the most cost-effective options for achieving the target threshold N watershed loads, including but not limited to, sewering and treatment for N control of sewage and septage at either centralized or de-centralized locations, and denitrifying systems for all private residences. 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. This adaptive management approach will incorporate the priorities and concepts included in the updated area wide management plan established under the Clean Water Act Section 208.

Table 8: Summary of the Septic System Loads, and the Loading Reductions Necessary to Achieve the TMDL by Reducing Septic System Loads Only (excerpted from Howes *et. al*, 2013, Table VIII-2)

Sub-embayment	Present Septic Load (kg/day)	Threshold Load (kg/day)	Threshold % change
Waquoit Bay	1.397	1.397	0.0%
Childs River- upper	9.929	1.986	-80.0%
Eel Pond- east branch	1.688	0.338	-80.0%
Eel Pond- south basin	0.458	0.458	0.0%
Eel Pond- west branch	12.548	5.019	-60.0%
Quashnet River	1.904	0.628	-67.0%
Hamblin Pond	3.427	0	-100.0%
Little River	0.885	0	-100.0%
Jehu Pond	2.888	0	-100.0%
Great River	2.674	0	-100.0%
Sage Lot Pond	1.132	0	-100.0%
Freshwater			
Childs River	8.134	1.627	-80.0%
Quashnet River	10.504	3.466	-67.0%
Red Brook	6.575	0.658	-90.0%
Total	64.142	15.576	-75.7%

Stormwater

EPA and MassDEP authorized most of the watershed communities of Falmouth, Mashpee and Sandwich for coverage under the NPDES Phase II General Permit for Stormwater Discharges from Small Municipal Separate Storm Sewer Systems (MS4s) in 2003. The revised MS4 permit took effect July 1, 2018. The NPDES permits issued in Massachusetts do not establish numeric effluent limitations for stormwater discharges, rather, they establish narrative requirements, including best management practices, to meet the following six minimum control measures and to meet State Water Quality Standards. The six measures include:

1. public education and outreach particularly on the proper disposal of pet waste
2. public participation/involvement
3. illicit discharge detection and elimination
4. construction site runoff control
5. post construction runoff control
6. pollution prevention/good housekeeping.

As part of their applications for Phase II permit coverage, communities must identify the best management practices they will use to comply with each of these six minimum control measures and the measurable goals they have set for each measure. Therefore, compliance with the requirements of the Phase II stormwater permit for the affected towns will contribute to the goal of reducing the nitrogen load as prescribed in this TMDL for the Waquoit Bay system watershed.

The town of Sandwich in their most recent Phase II MS4 Stormwater report to EPA (April 2016) noted significant accomplishments that included continued efforts to refine and improve mapping of catchment and subcatchment areas, stormwater mitigation of Mill Creek via BMP retrofits, monitor erosion control and illicit discharge identification and abatement, outreach and education with a household hazardous waste day and Community Pride Day (town-wide clean up), as well as continued Comprehensive Water Resources Management Plan Development to address issues town-wide.

The town of Mashpee in their 2013 Phase II MS4 Stormwater report to EPA note that they continue to map stormwater outfalls and update the GIS system as necessary. The town also noted that a number of roads in town had received stormwater improvements, outreach materials on Zone II public water supply areas and stormwater have been distributed to the citizenry, as well as, hazardous waste collections and infrastructure maintenance (street sweeping, catch basin cleaning etc.).

In their 2015 annual Phase II MS4 Stormwater report to EPA the town of Falmouth reports that they continue mapping their outfall maps and storm drain system and conducting field inspections to identify illicit discharges, sump pumps draining to roadways or catch basins and several LID projects under design or construction. Between 2012 and 2014, Falmouth had the help of AmeriCorps personnel to create an active outreach and education program. The town also notes purchase of a new street sweeper and rebuilt the catch basin cleaning truck. Salt brine is applied to roads instead of sand and salt mixtures during winter months.

Climate Change

MassDEP recognizes that long-term (25+ years) climate change impacts to southeastern Massachusetts, including the area of this TMDL, are possible based on known science. Massachusetts Executive Office of Energy and Environmental Affairs 2011Climate Change Adaptation Report: (http://bit.ly/MAClimateAdaptation) predicts that by 2100 the sea level could be from 1 to 6 feet higher than the current position and precipitation rates in the Northeast could increase by as much as 20 percent. However, the details of how climate change will affect sea level rise, precipitation, streamflow, sediment and nutrient loading in specific locations are generally unknown. The ongoing debate is not about whether climate change will occur, but the rate at and the extent to which it will occur and the adjustments needed to address its impacts. EPA's 2012 Climate Change Strategy (http://bit.ly/EPA_2012_ClimateStrategy) states: "Despite increasing understanding of climate change, there still remain questions about the scope and timing of climate change impacts, especially at the local scale where most water-related decisions are made." For estuarine TMDLs in southeastern Massachusetts, MassDEP recognizes that this is particularly true, where water quality management decisions and implementation actions are generally made and conducted at the municipal level on a sub-watershed scale.

EPA's Climate Change Strategy identifies the types of research needed to support the goals and strategic actions to respond to climate change. EPA acknowledges that data are missing or not available for making water resource management decisions under changing climate conditions. In addition, EPA recognizes the limitation of current modeling in predicting the pace and magnitude of localized climate change impacts and recommends further exploration of the use of tools, such as atmospheric, precipitation and climate change models, to help states evaluate pollutant load impacts under a range of projected climatic shifts.

In 2013, EPA released a study entitled, "Watershed modeling to assess the sensitivity of streamflow, nutrient, and sediment loads to potential climate change and urban development in 20 U.S. watersheds." (National Center for Environmental Assessment, Washington D.C.; EPA/600/R-12/058F). The closest watershed to southeastern Massachusetts that was examined in this study is a New England coastal basin located between Southern Maine and Central Coastal Massachusetts. These watersheds do not encompass any of the watersheds in the Massachusetts Estuary Project (MEP) region, and it has vastly different watershed characteristics, including soils, geography, hydrology and land use – key components used in a modeling analysis. The initial "first order" conclusion of this study is that, in many locations, future conditions, including water quality, are likely to be different from past experience. However, most significantly, this study did not demonstrate that changes to TMDLs (the water quality restoration targets) would be necessary for the region. EPA's 2012 Climate Change Strategy also acknowledges that the Northeast, including New England, needs to develop standardized regional assumptions regarding future climate change impacts. EPA's 2013 modeling study does not provide the scientific methods and robust datasets needed to predict specific long-term climate change impacts in the MEP region to inform TMDL development.

MassDEP believes that impacts of climate change should be addressed through TMDL implementation with an adaptive management approach in mind. Adjustments can be made as environmental conditions, pollutant sources, or other factors change over time. Massachusetts Coastal Zone Management (CZM) has developed a StormSmart Coasts Program (2008) to help coastal communities address impacts and effects of erosion, storm surge and flooding which are increasing due to climate change. The program, www.mass.gov/czm/stormsmart offers technical information, planning strategies, legal and regulatory tools to communities to adapt to climate change impacts.

As more information and tools become available, there may be opportunities to make adjustments in the TMDLs in the future to address predictable climate change impacts. When the science can support assumptions about the effects of climate change on the nitrogen loadings to the Waquoit Bay Embayment System the TMDL can be reopened, if warranted.

Implementation Guidance

The towns of Sandwich, Mashpee and Falmouth are 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.

DEP's MEP Implementation Guidance report (http://bit.ly/MEP_RestorationGuidance) with appendices (http://bit.ly/MEPrestapp) provides N loading reduction strategies that are available to the towns of Mashpee, Falmouth and Sandwich, 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 Towns of Mashpee, Falmouth and Sandwich are three of 237 communities in Massachusetts covered by the Phase II stormwater program requirements.

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. This adaptive management approach will incorporate the priorities and concepts included in the updated area wide management plan established under Clean Water Act Section 208.

Monitoring Plan

MassDEP is of the opinion that there are two forms of monitoring that are useful to determine progress towards achieving compliance with the TMDL. MassDEP's position is that implementation will be conducted through an iterative process where adjustments maybe needed in the future. The two forms of monitoring include 1) tracking implementation progress as approved in the CWMP and 2) monitoring water quality and habitat conditions in the estuaries, including but not limited to, the sentinel stations identified in the MEP Technical Report.

The CWMP will evaluate various options to achieve the goals set out in the TMDL report and the MEP 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 values are not fixed, the target threshold N concentrations at the sentinel stations are fixed. 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 believes 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 watershed communities to develop and refine monitoring plans that remain consistent with the goals of the TMDL. Through the adaptive management approach ongoing monitoring will be conducted and will indicate if water quality standards are being met. If this does not occur other management activities would have to be identified and considered to reach to goals outlined in this 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. Sandwich, Mashpee and Falmouth have demonstrated this commitment through the comprehensive wastewater planning that they initiated well before the generation of the TMDL. The Towns expect 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. Stormwater NPDES permit coverage will address discharges from municipally owned stormwater 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 towns implement this TMDL, the TMDL values (kg/day of N) will be used by MassDEP as guidelines for permitting activities and should be used by local communities as a management tool.

Public Participation

The public meeting to present the results of and answer questions on this TMDL was held on December 19, 2019 in the Selectman's meeting room in Falmouth Town Hall. Notice of the public meeting was issued through a press release, a notice was placed in the Massachusetts Environmental Policy Act (MEPA) Monitor, and an email was sent to town officials and volunteer groups. A copy of the draft TMDL was placed on the MassDEP website.

Patti Kellogg and Barbara Kickham with the MassDEP summarized the Mass Estuaries Project and described the Draft Total Nitrogen TMDL Report findings. Brian Dudley and Laura Blake, also with MassDEP, assisted with responding to questions. Public comments received at the public meetings and comments received in writing within a 30-day comment period following the public meeting were considered by the Department. This final version of the TMDL report includes both a summary of the public comments together with the Department's response to the comments and scanned images of the attendance sheets from the meetings (Appendix E). SMAST representatives at the public meeting included Brian Howes and Ed Eichner.

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Appendix A: Overview of Applicable Water Quality Standards

Water quality standards of particular interest to the issues of cultural eutrophication are dissolved oxygen, nutrients, bottom pollutants or alterations, 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. This brief summary does not supersede or replace 314 CMR 4.0 Massachusetts Water Quality Standards, the official and legal standards. A complete version of 314 CMR 4.0 Massachusetts Water Quality Standards is available online at https://www.mass.gov/regulations/314-CMR-4-the-massachusetts-surface-water-quality-standards

Applicable Narrative Standards

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)(b) states "Bottom Pollutants or Alterations. All surface waters shall be free from pollutants in concentrations or combinations or from alterations that adversely affect the physical or chemical nature of the bottom, interfere with the propagation of fish or shellfish, or adversely affect populations of non-mobile or sessile benthic organisms."

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 by the Department pursuant to 314 CMR 4.00. Any existing point source discharge containing nutrients in concentrations that would cause or contribute to cultural eutrophication, including the excessive growth of aquatic plants or algae, in any surface water shall be provided with the most appropriate treatment as determined by the Department, including, where necessary, highest and best practical treatment (HBPT) for POTWs and BAT for non POTWs, to remove such nutrients to ensure protection of existing and designated uses. Human activities that result in the nonpoint source discharge of nutrients to any surface water may be required to be provided with cost effective and reasonable best management practices for nonpoint source control."

Description of Coastal and Marine Classes and Numeric Dissolved Oxygen Standards

Excerpt from 314 CMR 4.05(4) (a):

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

1. Dissolved Oxygen. Shall not be less than 6.0 mg/l. Where natural background conditions are lower, DO shall not be less than natural background. Natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained.

Excerpt from 314 CMR 4.05(4) (b):

(b) Class SB. These waters are designated as a habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. In certain waters, habitat for fish, other aquatic life and wildlife may include, but is not limited to, seagrass. Where designated in the tables to 314 CMR 4.00 for shellfishing, these waters shall be suitable for shellfish harvesting with depuration (Restricted and Conditionally Restricted Shellfish Areas). These waters shall have consistently good aesthetic value.

1. Dissolved Oxygen. Shall not be less than 5.0 mg/l. Seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained. Where natural background conditions are lower, DO shall not be less than natural background.

Excerpt from 314 CMR 4.05(3) (b):

(b) Class B. These waters are designated as a habitat for fish, other aquatic life and wildlife, including for their reproduction, migration, growth and other critical functions, and for primary and secondary contact recreation. Where designated in 314 CMR 4.06, they shall be suitable as a source of public water supply with appropriate treatment ("Treated Water Supply"). Class B waters shall be suitable for irrigation and other agricultural uses and for compatible industrial cooling and process uses. These waters have consistently good aesthetic value.

1. Dissolved Oxygen. Shall not be less than 6.0 mg/l in cold water fisheries and not less than 5.0 mg/l in warm water fisheries. Where natural background conditions are lower, DO shall not be less than natural background conditions. Natural seasonal and daily variations that are necessary to protect existing and designated uses shall be maintained.

Waterbodies Not Specifically Designated in 314 CMR 4.06 or the tables to 314 CMR 4.00

Note many waterbodies do not have a specific water quality designation in 314 CMR 4.06 or the tables to 314 CMR 4.00**.** Coastal and Marine Classes of water are designated as Class SA and presumed High Quality Waters as described in 314 CMR 4.06 (4).

314 CMR 4.06(4):

(4) Other Waters. Unless otherwise designated in 314 CMR 4.06 or unless otherwise listed in the tables to 314 CMR 4.00, other waters are Class B, and presumed High Quality Waters for inland waters and Class SA and presumed High Quality Waters for coastal and marine

waters. Inland fisheries designations and coastal and marine shellfishing designations for unlisted waters shall be made on a case-by-case basis as necessary.

Applicable Antidegradation Provisions

Applicable antidegradation provisions are detailed in 314 CMR 4.04 from which an excerpt is provided:

Excerpt from 314 CMR 4.04:
4.04: Antidegradation Provisions

(1) Protection of Existing Uses. In all cases existing uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.

(2) Protection of High Quality Waters. High Quality waters are waters whose quality exceeds minimum levels necessary to support the national goal uses, low flow waters, and other waters whose character cannot be adequately described or protected by traditional criteria. These waters shall be protected and maintained for their existing level of quality unless limited degradation by a new or increased discharge is authorized by the Department pursuant to 314 CMR 4.04(5). Limited degradation also may be allowed by the Department where it determines that a new or increased discharge is insignificant because it does not have the potential to impair any existing or designated water use and does not have the potential to cause any significant lowering of water quality.

(3) Protection of Outstanding Resource Waters. Certain waters are designated for protection under this provision in 314 CMR 4.06. These waters include Class A Public Water Supplies (314 CMR 4.06(1)(d)1.) and their tributaries, certain wetlands as specified in 314 CMR 4.06(2) and other waters as determined by the Department based on their outstanding socio-economic, recreational, ecological and/or aesthetic values. The quality of these waters shall be protected and maintained.

(a) Any person having an existing discharge to these waters shall cease said discharge and connect to a Publicly Owned Treatment Works (POTW) unless it is shown by said person that such a connection is not reasonably available or feasible. Existing discharges not connected to a POTW shall be provided with the highest and best practical method of waste treatment determined by the Department as necessary to protect and maintain the outstanding resource water.

(b) A new or increased discharge to an Outstanding Resource Water is prohibited unless:

1. the discharge is determined by the Department to be for the express purpose and intent of maintaining or enhancing the resource for its designated use and an authorization is granted as provided in 314 CMR 4.04(5). The Department's determination to allow a new or increased discharge shall be made in agreement with the federal, state, local or private entity recognized by the Department as having direct control of the water resource or governing water use; or

2. the discharge is dredged or fill material for qualifying activities in limited circumstances, after an alternatives analysis which considers the Outstanding Resource Water designation and further minimization of any adverse impacts. Specifically, a discharge of dredged or fill material is allowed only to the limited

extent specified in 314 CMR 9.00 and 314 CMR 4.06(1)(d). The Department retains the authority to deny discharges which meet the criteria of 314 CMR 9.00 but will result in substantial adverse impacts to the physical, chemical, or biological integrity of surface waters of the Commonwealth

(4) Protection of Special Resource Waters. Certain waters of exceptional significance, such as waters in national or state parks and wildlife refuges, may be designated by the Department in 314 CMR 4.06 as Special Resource Waters (SRWs). The quality of these waters shall be maintained and protected so that no new or increased discharge and no new or increased discharge to a tributary to an SRW that would result in lower water quality in the SRW may be allowed, except where:

(a) the discharge results in temporary and short term changes in the quality of the SRW, provided that the discharge does not permanently lower water quality or result in water quality lower than necessary to protect uses; and

(b) an authorization is granted pursuant to 314 CMR 4.04(5).

(5) Authorizations.

(a) An authorization to discharge to waters designated for protection under 314 CMR 4.04(2) may be issued by the Department where the applicant demonstrates that:

1. The discharge is necessary to accommodate important economic or social development in the area in which the waters are located;

2. No less environmentally damaging alternative site for the activity, receptor for the disposal, or method of elimination of the discharge is reasonably available or feasible;

3. To the maximum extent feasible, the discharge and activity are designed and conducted to minimize adverse impacts on water quality, including implementation of source reduction practices; and

4. The discharge will not impair existing water uses and will not result in a level of water quality less than that specified for the Class.

(b) An authorization to discharge to the narrow extent allowed in 314 CMR 4.04(3) or 314 CMR 4.04(4) may be granted by the Department where the applicant demonstrates compliance with 314 CMR 4.04(5)(a)2. through 314 CMR 4.04(5)(a)4.

(c) Where an authorization is at issue, the Department shall circulate a public notice in accordance with 314 CMR 2.06. Said notice shall state an authorization is under consideration by the Department and indicate the Department's tentative determination. The applicant shall have the burden of justifying the authorization. Any authorization granted pursuant to 314 CMR 4.04 shall not extend beyond the expiration date of the permit.

(d) A discharge exempted from the permit requirement by 314 CMR 3.05(4) (discharge necessary to abate an imminent hazard) may be exempted from 314 CMR 4.04(5) by decision of the Department.

(e) A new or increased discharge specifically required as part of an enforcement order issued by the Department in order to improve existing water quality or prevent existing water quality from deteriorating may be exempted from 314 CMR 4.04(5) by decision of the Department.

(6) The Department applies its Antidegradation Implementation Procedures to point source discharges subject to 314 CMR 4.00.

(7) Discharge Criteria. In addition to the other provisions of 314 CMR 4.00, any authorized Discharge shall be provided with a level of treatment equal to or exceeding the requirements of the Massachusetts Surface Water Discharge Permit Program (314 CMR 3.00). Before authorizing a discharge, all appropriate public participation and intergovernmental coordination shall be conducted in accordance with Permit Procedures (314 CMR 2.00).

Appendix B: Summary of the Nitrogen Concentrations for Waquoit Bay Embayment System

Subembayment	Station ID	2002 mean	2003 mean	2004 mean	2005 mean	2006 mean	2007 mean	2008 mean	2009 mean	2010 mean	Mean*	standard deviation (all data)	number samples	Model Minimum	Model Maximum	Model Average
Upper Waquoit Bay	WB12	0.484	0.447	0.588	0.421	0.476	0.474	0.463	0.445	0.488	0.469	0.085	44	0.598	0.676	0.63
Lower Waquoit Bay	WB13	0.412	0.376	0.496	0.357	0.398	0.378	0.386	0.4	0.424	0.392	0.057	45	0.369	0.642	0.535
Quashnet River (freshwater)	WB06	0.504	--	0.451	0.424	0.513	0.49	0.508	0.597	0.593	0.516	0.117	29	0.294	0.567	0.427
Upper Quashnet River	WB07	0.67	0.574	0.653	0.504	0.739	0.638	--	0.626	0.597	0.632	0.196	24	0.428	0.577	0.521
Mid Quashnet River	WB08	0.768	0.897	0.676	0.692	0.736	0.862	1.212	0.577	0.839	0.791	0.242	30	--	--	--
Lower Quashnet River	WB09	0.586	0.58	0.694	0.524	0.674	0.698	0.792	0.655	0.598	0.633	0.127	32	--	--	--
Red Brook (freshwater)	WB05	0.643	--	0.629	0.461	0.562	0.548	0.506	0.55	0.563	0.561	0.086	25	0.701	0.75	0.725
Hamblin Pond	WB04	0.567	0.46	0.536	0.451	0.513	0.485	0.583	0.471	0.552	0.517	0.079	37	0.632	0.734	0.684
Hamblin Pond Drain	WB10	0.598	0.57	0.584	0.434	0.617	0.586	0.747	0.515	0.698	0.59	0.126	34	0.491	0.684	0.592
Jehu Pond	WB01	0.593	0.576	0.638	0.481	0.57	0.608	0.619	0.515	0.671	0.581	0.096	36	0.221	0.514	0.351
Upper Great River	WB02	0.679	0.558	0.714	0.442	0.569	0.594	0.599	0.513	0.62	0.585	0.125	33	0.293	0.469	0.382
Great/Little River	WB03	0.624	0.505	0.562	0.447	0.487	0.568	0.48	0.482	0.568	0.535	0.109	34	0.382	0.434	0.4
Upper Childs River	CR01	--	--	1.533	1.179	1.182	1.228	1.154	1.095	1.112	1.19	0.232	19	0.279	0.43	0.3
Mid Childs River	CR02	--	--	0.926	0.79	0.822	0.936	1.067	0.72	1.009	0.888	0.337	23	1.086	1.22	1.145
Lower Childs River	CR03	--	--	--	0.452	0.47	0.474	0.488	0.421	0.555	0.474	0.066	20	0.531	0.753	0.651
Upper Eel River	ER01	--	--	--	0.69	0.771	0.765	0.719	0.73	0.774	0.742	0.132	20	0.283	0.459	0.341
Lower Eel River	ER02	--	--	--	0.593	0.541	0.617	0.649	0.553	0.76	0.622	0.138	21	0.526	0.819	0.669
Eel Pond ER	ER03	--	--	--	0.454	0.362	0.411	0.364	0.376	0.455	0.404	0.059	19	0.301	0.651	0.428
Vineyard Sound	VS										0.28	0.065	196	0.28	0.445	0.307
Seapit River WB	WB11	0.501	0.54	0.617	0.543	0.585	0.46	0.594	0.531	0.491	0.528	0.078	33	--	--	--

Appendix C: Estimated waste load allocation (WLA) from runoff of all impervious areas within 200 feet of embayment waterbodies.

System Name	Impervious Area in 200 ft buffer (acres)[1]	Total Impervious Area in Watershed (acres)	Total Watershed Area (acres)	% Impervious of Total Watershed Area	Impervious Area in 200ft buffer as Percentage of Total Watershed Impervious Area	MEP Total Unattenuated Subwatershed Impervious Load (kg/day)	MEP Total Unattenuated Watershed Load (kg/day)[2]	Impervious buffer (200ft) WLA (kg/d)[3]	Buffer area WLA as percentage of MEP Total Unattenuated Subwatershed Load[4]
Waquoit Bay	8.3	23.5	1454.7	1.6%	35.4%	0.11	2.09	0.040	1.9%
Childs River- upper	14.3	112.0	636.3	17.6%	12.8%	0.71	13.14	0.091	0.7%
Eel Pond- east branch	10.3	25.4	228.8	11.1%	40.7%	0.14	2.17	0.058	2.7%
Eel Pond- south basin	2.0	5.0	80.4	6.2%	40.0%	0.02	0.52	0.010	1.8%
Eel Pond- west branch	19.5	205.4	1231.0	16.7%	9.5%	0.90	16.60	0.085	0.5%
Quashnet River	4.6	30.9	346.1	8.9%	14.9%	0.20	2.77	0.030	1.1%
Hamblin Pond	7.6	49.1	505.6	9.7%	15.5%	0.36	4.38	0.055	1.3%
Little River	5.9	13.7	61.3	22.4%	43.1%	0.09	1.09	0.041	3.7%
Jehu Pond	3.9	35.0	296.4	11.8%	11.1%	0.26	3.91	0.029	0.8%
Great River	9.4	47.9	657.3	7.3%	19.6%	0.38	3.67	0.074	2.0%
Sage Lot Pond	0.0	23.7	461.7	5.1%	0.0%	0.13	2.75	0.000	0.0%
Total	85.8	571.6	5959.6	9.6%	15.0%	3.32	53.10	0.514	1.0%

1- 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.
2- This includes the unattenuated nitrogen loads from wastewater from septic systems, fertilizer, runoff from both natural and impervious surfaces, atmospheric deposition to freshwater waterbodies and wastewater from one wastewater treatment facility.
3- The impervious area in 200ft buffer (acres) divided by total subwatershed impervious area (acres) then multiplied by total impervious subwatershed load (kg/day).
4- The impervious subwatershed buffer area WLA (kg/day) divided by the total subwatershed load (kg/day) then multiplied by 100.

Appendix D: 9 Total Nitrogen TMDLs and 3 Pollution Prevention TMDLs

Watersheds	MassDEP Segment ID	Impairment [TMDL Type]	TMDL (kg/day)
Waquoit Bay[1]	MA96-21	Oxygen (Dissolved), Estuarine Bioassessments [Restoration]	**14.04**
Childs River – upper	MA96-120[2]	Oxygen (Dissolved), Estuarine Bioassessments, Nutrient/Eutrophication Biological Indicators [Restoration]	**4.53**
Eel Pond - east		Oxygen (Dissolved), Estuarine Bioassessments, Nutrient/Eutrophication Biological Indicators	21.31
Eel Pond - south		Estuarine Bioassessments, Nutrient/Eutrophication Biological Indicators	1.19
Eel Pond - west		Oxygen (Dissolved), Nutrient/Eutrophication Biological Indicators	9.70
Eel Pond System[3]	MA96-121[2]	[Restoration]	**32.2**
Quashnet River[4]	MA96-20	Oxygen (Dissolved), Nitrogen (Total) [Restoration]	**11.25**
Hamblin Pond[3,4]	MA96-58	Nitrogen (Total), Estuarine Bioassessments [Restoration]	**8.19**
Little River[4]	MA96-61	Nitrogen (Total), Estuarine Bioassessments [Restoration]	**2.92**
Jehu Pond[4]	MA96-59	Nitrogen (Total), Estuarine Bioassessments [Restoration]	**8.60**
Great River[4]	MA96-60	Nitrogen (Total), Estuarine Bioassessments [Restoration]	**16.53**
Sage Lot Pond	MA96-119[2]	Estuarine Bioassessments, Nutrient/Eutrophication Biological Indicators [Restoration]	**2.09**
Freshwater			
Childs River	MA96-98	Not assessed for Nitrogen (Total) impairment, but TMDL needed since waterbodies are linked. [Protective]	**4.12**
Quashnet River	MA96-90	Not assessed for Nitrogen (Total) impairment, but TMDL needed since waterbodies are linked. [Protective]	**13.47**
Red Brook	MA96-25	Not assessed for Nitrogen (Total) impairment, but TMDL needed since waterbodies are linked. [Protective]	**2.10**
Waquoit Bay System Total			**120.02**

[1] Includes the Seapit River (MA96-122[2]).
[2] To be considered in a future Integrated List of Waters (303(d))
[3] The Eel Pond System includes Eel Pond-east, Eel Pond-west and Eel Pond-south.
[4] These TMDLs replace previously approved EPA TMDLs #33811through #33815.

Appendix E: Massachusetts Estuaries Project (MEP) Response to Comments

DRAFT TOTAL MAXIMUM DAILY LOAD (TMDL) REPORT FOR
WAQUOIT BAY (378.0)
MEGANSETT-SQUETEAGUE HARBORS (CN 374.0)
FALMOUTH INNER HARBOR (CN 396.0)
REPORTS DATED AUGUST 2019

PUBLIC MEETING ON DECEMBER 19, 2019
FALMOUTH TOWN HALL SELECTMEN'S MEETING ROOM,
FALMOUTH, MA

1) **What is Enhanced Nitrogen Removal?**

MassDEP Response: Enhanced nitrogen removal refers to techniques that can be implemented to increase or optimize nitrogen removal or containment. An example is maximizing nitrogen uptake by plants in wetlands areas that could be restored or expanded. Increased nitrogen removal can be achieved through Permeable Reactive Barriers (PRBs) where the nitrogen in the groundwater adsorbs to the material in the PRB. Shellfish aquaculture is in use in estuaries with the intent of decreasing nitrogen concentrations in the water column. These techniques do not address source reduction but are intended to reduce the amount of nitrogen reaching the estuaries.

2) **The scenario provided in the Technical Report directed 100% reduction of septic load in certain subwatersheds in Waquoit Bay? Is that correct and how did they come up with exactly 100%?**

MassDEP Response: The scenario provided in the Technical Report which was to reduce the septic nitrogen load by 100% in some select sub-watersheds (through sewering) is just one scenario to meet the nitrogen target at the sentinel station. SMAST's decision to select certain subwatersheds within Waquoit Bay is in part based on the density of development and feasibility to pursue sewering. Sewering in those areas was maximized. In some areas, the modeling may have indicated that even more than 100% nitrogen reduction through sewering would be needed to meet the threshold concentrations. The scenario presented in the Technical Report should be considered an illustration, not an engineering study, of what could be done to remove the needed nitrogen from the watershed.

3) **What happens if 100% removal through sewering is required to meet the target concentration in the estuary, but the town can only reduce (or sewer) a smaller amount?**

MassDEP Response: MassDEP strongly encourages the towns in the watershed(s) to work together on comprehensive planning so that the burden of nitrogen removal and sewering is distributed equitably. An overall, cooperative agreement provides greater flexibility, increased assurance, and a better chance of success. Note that there is flexibility in how towns meet the needed reductions through your Comprehensive Water Resources Management Plan (CWRMP).

The Technical Report provided just one scenario for each estuarine system that meets the target concentrations. Completing additional modeling and analyses may reveal other scenarios that may be pursued to meet the necessary reductions and recover the benthic and eelgrass habitats of the estuaries and harbors.

4) Is there a possibility for trading credits?

MassDEP Response: MassDEP is considering the possibility of trading nitrogen credits. There can be some mixing and matching to meet the target concentrations so that the burden is shared proportionally and equitably.
SMAST Response: As part of developing the nitrogen reduction strategy, we looked for areas that were potentially "sewerable" and were densely developed to maximize reductions in total nitrogen in the watershed. If Hamblin and Jehu Ponds and the associated rivers on the east side of Waquoit Bay in Mashpee, were sewered, these areas could see habitat recovery without waiting for work to be completed in other parts of the estuary system, such as Eel River and Childs River to the west. You can mix and match nitrogen removal between subwatersheds, however, not all nitrogen removal has the same benefit. Nitrogen reduction further up in the watershed provides long-term improvement compared to nitrogen removal close to where it discharges to the estuary. Mixing and matching of nitrogen reduction scenarios between subwatersheds such as Waquoit Bay, must be done through estuary specific modeling.

5) How long does it take to see effects on eelgrass after the target threshold is met?

MassDEP Response: The time it takes to observe regrowth of eelgrass is very estuary specific. It depends on where the nitrogen removal or the sewering occurred which will inform you on the time of travel to the estuary. Each Technical Report broke out the travel time within subwatersheds to less than, and greater than, a ten-year travel time to the estuary. When and if the source of all the nitrogen is removed, it will still take years for the nitrogen in the groundwater to discharge to the estuary. If the town sewers homes close to the bay, it may be 1 or 2 years to see some improvement, particularly if there was still some eelgrass remaining in the embayment. But it will take several years to see the full recovery. More generally it could take several years to see eelgrass return to the estuary after source reduction begins.

6) What happens if we hit the target threshold at the sentinel station, let's say for several consecutive years, but eelgrass does not return?

MassDEP Response: The goal of the TMDL is to restore the estuary habitats for eelgrass and benthic infauna and that the target concentrations are the guide to getting there. If we reach the target concentration at the sentinel stations then the TMDL allows, through the process of Adaptive Management, a re-evaluation of the nitrogen reduction strategy and lowering of the target concentration. This may require additional modeling to determine if additional nitrogen reductions are needed. The threshold concentration is a target, but the final goal is habitat restoration.

7) There was a lot of negative benthic flux in the sediments as reported in the Waquoit Bay Technical Report. The negative sediment benthic flux was then set to zero for the TMDL. Why didn't that change the percent reduction needed?

MassDEP Response: The TMDLs for the MEP are the sum of the watershed nitrogen loads, the background or atmospheric deposition of nitrogen, and the benthic sediment flux. The atmospheric deposition and the benthic sediment flux are not locally controllable therefore we focus on the reduction of nitrogen sources in the watershed (septic systems, fertilizers, stormwater, landfills, etc). The percent reduction of the nitrogen load in the watershed to meet the threshold concentration at the sentinel stations (controllable load), is independent of the benthic flux and atmospheric deposition (not controllable). In the case of Waquoit Bay, the model predicted a large negative benthic sediment flux with reductions in watershed nitrogen loading. In establishing the MEP TMDLs, MassDEP sets negative benthic sediment flux to zero, which is conservative and adds to our margin of safety. (A negative flux assumes that the sediment is a nitrogen sink.) By setting the benthic sediment flux to zero, the value of the TMDL is larger than if we included a negative flux, but it does not change the reductions needed within the watershed to meet the target concentrations in the estuaries.

8) **The Town of Falmouth and the Buzzards Bay Coalition are looking for Innovative Alternatives (IA) for nitrogen reducing septic systems with effluent concentrations under 10 ppm. The IA systems that have been approved by MassDEP have an average effluent of 19 ppm, however, the high cost of IA systems does not justify construction of a system with effluent concentrations of 19 ppm. Falmouth would like assistance from the State in getting approved IA technology that will reliably get below 10 ppm and is reasonably priced. Other states are way ahead of us.**

MassDEP Response: Other states lack the rigorous review that Massachusetts requires but also, the technologies approved by other states are not necessarily intended for nitrogen reduction. We are looking at very high levels of nitrogen treatment and the appropriate technologies do not yet exist. Although in the past three to four years, we have started to see promising new technologies with effluent concentrations less than 19 ppm, not down to 10 ppm. Approval of IA systems through the State's rigorous Title 5 process takes a minimum of 4.5 years. New I/A technologies require piloting up to 15 systems for 18 months. If provisional approval is granted, three years of data must be collected from 50 systems. The target effluent concentration must be met for 90% of the data collected under provisional approval before the system will be approved for general use.

Developing these new technologies is resource intensive, however, the State supported early research on IA systems conducted at the Massachusetts Alternative Septic System Test Center through Section 319 Grants. MassDEP will accept data from other states if the data collection is as rigorous as we would require. Non-governmental Organizations (NGOs) such as the Barnstable Clean Water Coalition and Buzzards Bay Coalition have been tremendously helpful in getting more of these systems in the ground in sufficient numbers within a watershed to monitor operations and collect data. MassDEP needs to be confident that the technology works so that we do not approve and install expensive treatment systems, only to realize in the future that the technology was inadequate and must be replaced.

9) **There used to be an early spring algal bloom, but now there is only a summer bloom. Why is that?**

Response by Member of the Water Quality Management Committee: In the past, we used to observe algal bloom in the spring and again in the late summer, however, now we only observe the late summer algal bloom. We attribute the lack of an early bloom due to increasing ocean temperatures rather than to the excess nitrogen. There are more jellyfish and other marine organisms that move in and eat the algae that created the early bloom. The late blooms still occur because of the amount/extent of the algae is greater than the number and types of organisms that consume it.

10) **Megansett Harbor is located in Falmouth and Squeteague Harbor is located in Falmouth, and the majority of the watersheds for both are within Bourne. Is a municipal agreement between the towns required?**

MassDEP Response: There are three ways the towns could approach this. First you could do a cooperative agreement with Bourne and develop a combined plan, a Comprehensive or Targeted Watershed Management Permit. This would require an Inter-Municipal Agreement (IMA). A second approach, Falmouth could address nitrogen reduction strategies within their municipal boundaries alone and Bourne could do the same. The third option, each town can address nitrogen reductions according to the percentage of the watershed that is within their respective municipal boundaries. The problem with the second and third approaches is that if only one town pursues nitrogen reduction, the estuaries will not likely see habitat recovery within an acceptable time frame.

11) **Presentation by Ron Zweig: I would like to provide the example of Great Pond in Falmouth that is under evaluation with a draft water quality improvement scenario and consider Adaptive Management. For Great Pond, the current approach is to remove excess nitrogen loading on an annual mass balance basis required to achieve the nitrogen TMDL, using development of sewers in two sub-areas, a pilot permeable reactive barrier, stormwater management, nitrogen, credit from fertilizer reduction per the Town's bylaw to limit its use and shellfish aquaculture.**

    I would like you to consider one scenario for Great Pond shows that the nitrogen TMDL could be achievable during only the warmer months (May - September) by implementing all of the non-traditional interventions, only including sewers in sub-area 1. However, during the cold months when there would be no benefit from shellfish aquaculture, the nitrogen concentration would exceed the TN TMDL; but likely with little adverse effect during that period. Also, from the Great Pond MEP report, freshwater inflows from the Coonamessett River and groundwater seepage plus precipitation, there are just over 11 volume turnovers, with flows to Vineyard Sound, without considering additional freshening from tidal exchanges. For a preliminary draft comparison of the two approached, please see the slide below:

Draft Concept to Achieve Nitriogen TMDL and Nitrogen TMDL Alternative for Great Pond esturary in Falmouth, MA (All figures in kg-N per year)

	TMDL - MEP 12 months	TMDL Alternative May - Sept: 5 months (42%)
Annual N Removal Target	**12,154**	**5,064**
N Reduction Intervention Options		
Town Fertilizer Control By-law (25% N load credit)	425	425
Permeable Reactive Barrier (300 ft)	1,325	552
Stormwater (25% N runoff per NDPESP)	580	242
Shellfish Aquaculture (10 acres)	1,700	1,700
Existing Sewer Area (253 units) 1/	1,207	503
New Sewer -- Sub-area 1 (825 units) 2/	3,985	1,660
New Sewer -- Sub-area 2 (687 units) 2/	3,280	
Total Removal	**12,502**	**5,082**

1. Existing Little Pond Sewer Sevice Area partially within Great Pond watershed
2. At 4.772 kg-N/unit/year per MEP

Prepared by Ron Zweig, Falmouth Resident

MassDEP Response: TMDLS are required under the Clean Water Act to be representative of a daily load. The plan presented is the same daily load reduction but only over the summer months, which represents only a 42% reduction of the TMDL that is in place for the Great Pond estuary. The MEP model results provided load estimates to meet the target concentrations at the sentinel stations that will bring habitat recovery to the estuaries.

This plan does not meet the necessary load reductions. Even a seasonal reduction of 100% of the required annual load reduction in place over the summer months would not provide adequate protection. This plan does not consider the travel time delay – the time it takes for nitrogen entering the groundwater to eventually reach the estuaries. Reductions in the summer would not be immediately observed in the estuaries and would allow excess TN into the system for the remainder of the year. The plan you present does not take into consideration that the tidal flushing is far greater than the freshwater exchange. The plan does not consider that the sediment could be acting as a sink and that the nitrogen isn't flushed, but rather is entrained in the system.

Each TMDL that is developed out of the MEP has language that allows each town to meet the load reductions of the TMDL in any way they wish as long as they demonstrate that they can meet the target concentrations and recover the habitat. If the plan is different than the scenario proposed in the Final Tech Report, this would require additional modeling of the system to verify that the new scenario will be effective. This proposed plan seems to be a partial implementation of the MEP scenario. Keep in mind the town can address the TMDL load reductions in a phased manner with monitoring to record progress to meeting the targets.

Adaptive management allows for mid-course corrections to acknowledge changing conditions, advances in technology, etc. For example, if the target concentration is met at the sentinel station, but we do not observe estuarine recovery, then we may have to remodel the system, decrease the target concentration and require additional load reductions. Alternately if we record <u>*sustainable*</u> *improvement in habitat before reaching the target threshold, we could reduce the TN reduction needed.*

For clarification, an Alternative TMDL is not an option when there is a TMDL in place. The Alternative TMDL option is pursued to begin the implementation process prior to completion of a formal TMDL and must have the goal of meeting Massachusetts Surface Water Quality Standards and recovering habitat for eelgrass and or benthic habitat.

12) We have good information on nitrogen removal using shellfish. What does MassDEP think about the use of aquaculture?

MassDEP Response: Aquaculture or shellfish beds complement nitrogen removal and have shown some promise in water quality improvements. Though aquaculture does not address source control or reduction, it may help or supplement larger scale nitrogen reduction strategies. Closure of shellfishing beds is generally due to bacterial contamination and not necessarily nutrient enrichment. The most direct way to address excess nitrogen is through source control and reduction, however MassDEP understands that alternative methods may be used to assist in reducing the impacts of excess nitrogen. Several towns have explored oyster cultivation projects for water quality improvement including Wellfleet, Mashpee, Orleans and Falmouth. A lot of research is currently being conducted on the complicated and poorly understood shellfish nitrogen cycle, (ie. the uptake and release of nitrogen by shellfish).

13) The Buzzards Bay Coalition BBC encourages MassDEP to send these TMDLs to EPA for final approval as soon as possible.

MassDEP Response: *Thank you for your support of the TMDL. We will do our best to finalize the TMDL is a timely manner.*

14) BBC requests DEP expedite alternative technologies.

MassDEP Response: Please refer to the response to question 8 above.

15) Why are the TMDLs all different?

MassDEP Response: Every waterbody is different in the size and type of contributing land-uses, hydrology, bathymetry, and water quality and degree of impairment. The MEP was designed to provide estuary specific implementation guidance to meet the target concentrations, instead of a "one size fits all" approach. Although the target concentrations for eelgrass and benthic infauna habitat restoration are similar between estuaries, the restoration strategies (including targeted sewering) differ between watersheds.

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Email from Ron Zweig; rdzweig@gmail.com dated 12/20/2019
Dear Brian and Barbara,
Firstly, thanks for attending and presenting at the Falmouth Water Quality Management Committee meeting yesterday.
Regarding the point I made at the meeting about the comparison of the two tables from on the percent watershed reduction required when Benthic Flux figures were zeroed versus from negative values (used previously via the MEP), having no impact on the watershed reductions to meet the nitrogen TMDLs, I attach below the respective tables from the SMAST-MassDEP March 2013 and the EOEEA, DEP, BWR August 2019 reports for the Waquoit Bay system as an example. As can be seen when the Benthic Flux figure is changed from -56.779 to 0 kg-N/day,
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the required watershed nitrogen reduction percentage remains the same. It is unclear to me why the percentage N reduction would not increase. Also, Footnote 3 in the 2013 report's table indicates that the Benthic Flux was estimated based on the future flux when the watershed loads have been reduced.

Table ES-2. Present Watershed Loads, Thresholds Loads, and the percent reductions necessary to achieve the Thresholds Loads for the Waquoit Bay system.

Sub-embayments	Present Watershed Load [1] (kg/day)	Target Threshold Watershed Load [2] (kg/day)	Direct Atmospheric Deposition (kg/day)	Benthic Flux Net [3] (kg/day)	TMDL [4] (kg/day)	Percent watershed reductions needed to achieve threshold load levels
WAQUOIT BAY SYSTEM						
groundwater sources						
Waquoit Bay	2.088	2.088	11.956	-58.779	-42.735	0.0%
Childs River - upper	12.019	4.076	0.455	-4.291	0.240	-66.1%
Eel Pond - east branch	2.170	0.820	1.011	19.480	21.310	-62.2%
Eel Pond - south basin	0.523	0.523	0.663	-4.632	-3.445	0.0%
Eel Pond - west branch	16.337	8.808	0.890	-2.900	6.798	-46.1%
Quashnet River	2.773	1.497	0.252	9.496	11.245	-46.0%
Hamblin Pond	4.381	0.953	1.529	5.712	8.194	-78.2%
Little River	1.096	0.211	0.156	2.554	2.922	-80.7%
Jehu Pond	3.912	1.025	0.674	6.897	8.596	-73.8%
Great River	3.671	0.997	1.307	14.222	16.526	-72.8%
Sage Lot Pond	2.753	1.622	0.471	-2.726	-0.633	-41.1%
surface water sources						
Childs River	10.622	4.115	-	-	4.115	-61.3%
Quashnet River	20.507	13.469	-	-	13.469	-34.3%
Red Brook	8.014	2.096	-	-	2.096	-73.8%
Waquoit Bay System Total	90.866	42.300	19.364	-12.967	48.697	-53.4%

(1) Composed of combined natural background, fertilizer, runoff, and septic system loadings.
(2) Target threshold watershed load is the load from the watershed needed to meet the embayment threshold concentrations identified in Table ES-1.
(3) Projected future flux (present rates reduced approximately proportional to watershed load reductions).
(4) Sum of target threshold watershed load, atmospheric deposition load, and benthic flux load.

Table 7: The Total Maximum Daily Loads (TMDL) for the Waquoit Bay System sub-embayments.

Subembayment	Present Watershed Load (kg/day)	Target Watershed Load[1] (kg/day)	Atmospheric Deposition (kg/day)	Benthic Flux[2] (kg/day)	TMDL[3] (kg/day)	Percent Reductions
Groundwater						
Waquoit Bay	2.09	2.09	11.96	0.00	14.04	0.0
Childs River - upper	12.02	4.08	0.46	0.00	4.53	-66.1
Eel Pond - east	2.17	0.82	1.01	19.48	21.31	-62.2
Eel Pond - south	0.52	0.52	0.66	0.00	1.19	0.0
Eel Pond - west	16.34	8.81	0.89	0.00	9.70	-46.1
Quashnet River	2.77	1.50	0.25	9.50	11.25	-46.0
Hamblin Pond	4.38	0.95	1.53	5.71	8.19	-78.2
Little River	1.10	0.21	0.16	2.55	2.92	-80.7
Jehu Pond	3.91	1.03	0.67	6.90	8.60	-73.8
Great River	3.67	1.00	1.31	14.22	16.53	-72.8
Sage Lot Pond	2.75	1.62	0.47	0.00	2.09	-41.1
Freshwater						
Childs River[4]	10.62	4.12			4.12	-61.3
Quashnet River[4]	20.51	13.47			13.47	-34.3
Red Brook[4]	8.01	2.10			2.10	-73.8
Waquoit Bay System Total	90.87	42.30	19.36	58.36	120.02	-53.4

1- Target threshold watershed load is the load from the watershed needed to meet the embayment threshold concentrations identified in Table 4.
2 -Projected sediment N loadings obtained by reducing the present loading rates (Table 5) proportional to proposed watershed load reductions and factoring in the existing and projected future concentrations of PON. (Negative fluxes set to zero.)

Also, on the question about timing that Brian Dudley had raised in the scenario I presented some clarification is needed. In so far as the existing and future sewer operation, PRB function and watershed reduction etc., except for the shellfish component, they would function on a year around basis. The benefits of shellfish would only be realized during the growing season, just prior to which it would be implemented each year. The second column in the table I showed (below attached) shows what the amount of nitrogen that would need to be removed to reduce the nitrogen load to achieve the Sentinel Threshold/N TMDL, during the growing season (about five months) from all interventions -- year around and seasonal.

Draft Approach to Achieve Estuary Restoration via Phased, Adaptive Management Approach for Great Pond Esturary in Falmouth, MA (All figures in kg-N per year)

	N TMDL - MEP 12 months	Phase 1 per Falmouth Plan May - Sept: 5 months (42%)
N Removal Target	**12,154**	**5,064**
N Reduction Intervention Options		
Town Fertilizer Control By-law (25% N load credit)	425	425
Permeable Reactive Barrier (300 ft)	1,325	552
Stormwater (25% N runoff per NDPESP)	580	242
Shellfish Aquaculture (10 acres) 1/	1,950	1,950
Existing Sewer Area (253 units) 2/	1,207	503
New Sewer -- Sub-area 1 (811 units) 3/	3,870	1,613
New Sewer -- Sub-area 2 (687 units) 3/	3,280	
Total Removal	**12,637**	**5,284**

1. Nitrogen removal lowest estimate -- 62% of maximum estimate.
2. Existing Little Pond Sewer Sevice Area partially within Great Pond watershed
3. At 4.772 kg-N/unit/year per MEP

The Great Pond estuary could be an excellent opportunity to pilot the concept under the first phase of Falmouth's plan to remediate the water quality in that estuary per the current plan. Whether this strategy would be as effective as envisioned would need to be verified via a monitoring program of N concentrations in the water column during the growing season as well as the potential resultant impact on the recovery of biota in the estuary. If unsuccessful, a second phase of sewer expansion or other interventions in the watershed would then be initiated.
I hope this makes some of what I presented yesterday clear enough. Your views, any questions or need for further clarification would be welcome.
Thanks again.
With best wishes to you and your families for the holiday season.
Respectfully yours,
Ron Zweig

MassDEP Response: See responses to comments 7 and 11 above.

buzzards
BAY
COALITION

January 21, 2020

Barbara J. Kickham, TMDL Section Chief
MA Department of Environmental Protection
Watershed Planning Program
8 New Bond Street
Worcester, MA 01616

Re: **Buzzards Bay Coalition Requests the Immediate Approval as Final of the Megansett-Squeteague Harbor Estuarine System Total Maximum Daily Loads for Total Nitrogen (CN-452.0)**

Dear Ms. Kickham,

The Buzzards Bay Coalition (Coalition) has reviewed the Draft Megansett-Squeteague Harbor Estuarine System Total Maximum Daily Loads for Total Nitrogen (CN-452.0) dated August 2019 (draft Megansett-Squeteague TMDL). The Coalition urges the Massachusetts Department of Environmental Protection (MassDEP) to send the draft Megansett-Squeteague TMDL to the US Environmental Protection Agency (EPA) to approve as final. This letter follows our comments at the public meeting in Falmouth on December 19, 2019.

The draft Megansett-Squeteague TMDL confirms the need for nitrogen reductions. The TMDL forms the basis for the towns of Falmouth and Bourne to create plans for how they will reduce nitrogen pollution in the Megansett-Squeteague watershed to meet the TMDL. Delay in TMDL approval will postpone and hinder local action on nitrogen reductions and lead to further degradation of Megansett and Squeteague Harbors.

The Coalition is a membership-supported non profit organization dedicated to the restoration, protection and sustainable use and enjoyment of Buzzards Bay and its watershed including the watersheds of all three estuary systems. The Coalition is supported by more than 10,000 individuals, families, and businesses throughout the region including over 1,400 members affected by water quality in Falmouth and 647 members affected by water quality in Bourne.

The Coalition requests that the MassDEP and EPA consider the following comments in assessing whether these TMDLs successfully achieve water quality standards in Megansett and Squeteague Harbors.

www.savebuzzardsbay.org
114 Front Street, New Bedford, Massachusetts 02740 | Tel: 508-999-6363 Fax: 508-984-7913
21 Luscombe Avenue, Woods Hole, Massachusetts 02543 | Tel: 508-540-6222

Background:

The Towns of Falmouth and Bourne thrive on clean, productive and beautiful marine waters. Swimming, fishing, boating, fin-fishing, and shellfishing all support the local economy. However, as recognized by the draft TMDLs, the continued degradation of water quality due to nitrogen pollution in these estuaries reduces their recreational and commercial values.

The Federal Clean Water Act requires the Commonwealth of Massachusetts to identify waters that fail to meet water quality standards. The state is required to draft TMDLs establishing the maximum load (amount) of pollution from all sources that the identified water may receive and still meet water quality standards. The nitrogen capacity of Megansett and Squeteague Harbors were evaluated through the Massachusetts Estuaries Project (MEP) and the Megansett-Squeteague MEP report was finalized in 2015. The MEP report documented impairment of the water bodies and the need for nitrogen reductions.

The water quality in Megansett and Squeteague Harbors is degraded by nitrogen pollution. High nitrogen loads from septic systems, stormwater, and fertilizers cause low dissolved oxygen levels, elevated algae levels, loss of eelgrass, and decreased diversity and quantity of marine animals living on the seafloor. During the past 28 years, the Coalition has collected water quality data from three sites in Squeteague Harbor, and five sites in Megansett Harbor that clearly documents this impairment, including common incidences of dissolved oxygen levels less than 6 mg/L. Without reduction, these nitrogen loads could lead to further water quality and habitat degradation including fish kills, unpleasant odors and scums, and loss of critical marine animal communities.

Major Findings of the TMDL:

Both Megansett and Squeteague Harbors are listed as waterbodies needing at TMDL for nutrients. There has been significant decline in eelgrass coverage since 1995 in Megansett Harbor and the benthic infauna habitat has been degraded in Squeteague Harbor and the Megansett Channel. The draft Megansett-Squeteague TMDL establishes a target threshold concentration for total nitrogen in outer Megansett Harbor of 0.35 mg/L at the sentinel station MG2. The draft Megansett-Squeteague TMDL asserts that water quality standards for the entire system will be met when this target concentration is met, which will lead to improved water clarity, restoration of eelgrass habitat, and high quality habitat for seafloor species.

To meet the target thresholds and obtain water quality standards requires reductions in the watershed nitrogen loads of all three areas (17% in Megansett Harbor, 7.5% in Megansett Channel, and 5.6% in Squeteague Harbor), which equates to a 12% reduction to the whole system. The draft Megansett-Squeteague TMDL presents a scenario of meeting the target threshold via reductions from septic systems. A 19.3% reduction of the existing load from septic systems would achieve the target threshold nitrogen concentration of 0.35 mg/L at the sentinel station.

TMDL Implementation:

The draft Megansett-Squeteague TMDL presents a single scenario for nitrogen load reduction focused on septic system load removal. Targeting septic systems is prudent since the majority of the total controllable nitrogen load is from septic systems. It is now the responsibility of the Towns to develop and implement a Comprehensive Wastewater Management Plans (CWMP) that will assess the most cost-effective options for achieving the target nitrogen watershed loads, including possible sewering at either centralized or de-centralized (i.e., neighborhood scale) locations and the use of nitrogen-reducing septic systems.

The Coalition looks forward to working with the Town of Falmouth, Town of Bourne, MassDEP, EPA, and local stakeholders in the development and implementation of CWMPs for Megansett and Squeteague Harbors. The Coalition has partnered with homeowners around the watershed to upgrade to nitrogen-reducing septic systems, including 30 homeowners around West Falmouth Harbor in collaboration with the Town of Falmouth. This effort has shown the capability of the systems to provide significant nitrogen reductions and the Coalition is ready to provide information on the learnings of these efforts for application in places such as the Megansett-Squeteague watershed.

Comments:

In order to expeditiously proceed with nitrogen reduction planning and implementation, the Coalition urges the MassDEP to send the draft Megansett-Squeteague TMDL to the EPA to approve as final as soon as possible. However, we request that EPA and MassDEP consider the following comments in the implementation of these TMDLs and in their future updates. We do not suggest that any of the issues discussed below justify re-evaluation or further delays in issuance of the draft Megansett-Squeteague TMDL.

1. **The TMDLs' categorization of all septic systems into the Load Allocation is inaccurate.**

The MEP technical report acknowledges that the geology of Cape Cod and the Islands allows water to move rapidly through the ground, and the draft TMDL includes stormwater from impervious surfaces within 200 feet of the shoreline as point sources and includes it in the Waste Load Allocation. Septic systems within the watershed of Megansett-Squeteague Harbor should also be included in the Waste Load Allocation. The rapid movement of wastewater from septic systems to coastal waters, without significant attenuation of nitrogen, makes it appropriate to consider septic systems as part of the Waste Load Allocation. Nevertheless, we encourage EPA to finalize the draft Megansett-Squeteague TMDL, but suggest that MassDEP and EPA develop a methodology for allocating septic systems into the Waste Load Allocation portion of TMDLs in order to more effectively regulate septic systems as the primary point source of nitrogen in southeastern Massachusetts estuaries.

2. **The effects of climate change on water quality have not been adequately addressed in this TMDL; a larger Margin of Safety should be considered in future TMDLs.**

The TMDL states that "MassDEP believes that impacts of climate change should be addressed through TMDL implementation with an adaptive management approach in mind." Research into the Coalition's long-term water quality database, attached here, indicates Buzzards Bay waters are warming. At the same time, the relationship between nitrogen concentrations and algae growth (as measured by algal pigment concentrations) has shifted, with higher levels of algae growth occurring in more recent years than 25 years ago at the same nitrogen concentration. This shift in the relationship suggests that with a warming climate, greater algae growth and ecological impairment may occur than expected based on historic nitrogen concentrations.

The draft TMDL anticipates that an adaptive management approach will be utilized to assess the effectiveness of the TMDL and CWMP implementation. The adaptive management approach provides an opportunity to incorporate new understandings such as the effect of temperature on algae growth. To restore water quality, it is critical that adaptive management is effectively implemented and additional steps are taken if necessary.

3. **Eelgrass recovery targets may require lower nitrogen thresholds.**

Extensive eelgrass loss has occurred over the last century in Megansett Harbor with a very dramatic decline between 1951 and 1995. Since 1995, additional significant losses have occurred, with almost 40% of the remaining eelgrass disappearing between 1995 and 2012. The draft TMDL's primary restoration focus for the outer basin of Megansett Harbor is the recovery and protection of eelgrass habitat. A nitrogen threshold of 0.35 mg/L at sentinel station MG2 was selected as a target for restoring eelgrass.

The total nitrogen concentration at station MG2, as measured by the Baywatchers Monitoring Program fluctuated around the threshold level of 0.35 mg/L between 2000 and 2013. During this time period, eelgrass loss occurred. This suggests that the total nitrogen threshold of 0.35 mg/L may need to be maintained consistently for a number of years for eelgrass restoration to occur or that a lower total nitrogen concentration is required. Monitoring of both the nitrogen concentrations and eelgrass recovery will be required to assess whether nutrient reductions result in consistently lower nitrogen concentrations at the sentinel station and whether this allows for eelgrass recovery. Adaptive management plans need to anticipate and react to this monitoring information.

4. **An implementation schedule and monitoring plan should be promptly developed.**

The establishment of this TMDL anticipates that actions will be taken to meet the TMDL so that Megansett and Squeteague Harbors will be restored and meet water quality standards. We encourage MassDEP to work with the towns to develop a timeframe for TMDL implementation and a plan for monitoring. The timeframe should lay out a set of milestone goals that the towns can work towards achieving.

The TMDL states that "existing monitoring programs which were designed to thoroughly assess conditions and populate water quality models can be substantially reduced for compliance monitoring purposes." The TMDL indicates that about half the current effort would be sufficient to observe water quality changes. The MassDEP should clearly define what exactly it means by this.

Since 1992, through its Baywatchers Monitoring Program, the Coalition has performed summertime water quality monitoring in Megansett and Squeteague Harbors. This data forms the long-term water quality monitoring records used in the development of the MEP report that the TMDL is based upon. The Coalition intends to continue our water quality monitoring program and provides our data free of charge to any interested parties.

Funding for the Baywatchers Monitoring Program comes from a variety of sources including grants from federal and state sources, private foundations, and member contributions. For much of its history, the Coalition has received significant annual funding (~$125,000) from the MA State Legislature. There is $75,000 to support the Baywatchers Monitoring Program in the FY20 State Budget. As we consider how to modify our program with limited resources, MassDEP needs to clarify what it will require for monitoring of TMDL compliance.

Summary:

The issuance of this TMDL is a critical step in restoring the water quality of Megansett and Squeteague Harbors. The draft TMDL confirms the need for nitrogen reductions and requires the towns of Falmouth and Bourne to create plans for how they will reduce nitrogen to meet the TMDL. The Coalition urges the MassDEP to send the draft Megansett-Squeteague TMDL to the EPA to approve as final so that the towns of Falmouth and Bourne can begin planning for how to meet the required nitrogen reductions.

Sincerely,

Mark Rasmussen, President
Buzzards Bay Coalition

Attachment

cc: Kathleen Theoharides, MA Secretary of Energy & Environmental Affairs

Martin Suuberg, MassDEP Commissioner
Patti Kellogg, Bureau of Water Resources, MassDEP – SERO
Kenneth Moraff, US EPA

Town of Falmouth
- Board of Selectmen
- Water Quality Management Committee
- Conservation Commission
- Board of Health
- Planning Board
- Wastewater Department

Town of Bourne
- Board of Selectmen
- Sewer Commissioners
- Conservation Commission
- Board of Health
- Planning Board
- Department of Public Works

US Congressman William Keating
Representative David Vieira
Representative Dylan Fernandes

Cape Cod Commission

Attachment:
Rheauban JE, Williamson S, Costa JE, Glover DM, Jakuba RW, McCorkle DC, Neill C, Williams T, and Doney SC. 2016. Spatial and temporal trends in summertime climate and water quality indicators in the coastal embayments of Buzzards Bay, Massachusetts. Biogeosciences, 13, 253-265.

MassDEP Response: Thank you for your support of the TMDL for the Megansett-Squeteague Harbors system. In addition, thank you for your long-term commitment (>25 years) to data collection efforts in this estuary and throughout Buzzards Bay. The importance of these data cannot be overstated. Your major comments are addressed below.

The TMDL's categorization of all septic systems into the Load Allocation portion of the draft Megansett-Squeteague Harbors TMDL is inaccurate.

MassDEP Response: The scientific analysis underlying TMDLs is designed to address pollutant loading based on watershed scale modeling. The Linked Model that was used to develop the TMDL is not a fate and transport model that predicts the movement of individual pollutants (e.g., nitrate) in groundwater from a particular source or sources. Instead, it is designed to assess the sensitivity to nitrogen loading within the embayment; the assimilative capacity for nitrogen within that surface water; and water quality responses within the embayment to changes in nitrogen loading rates (i.e., as opposed to measuring nitrogen loads from particular sources). Accordingly, the Linked Model does not contain the type of data or level and scale of analysis necessary to predict the fate and transport of pollutants through groundwater from any specific *source or to support a specific determination that a discharge to the ground or groundwater has a direct and immediate hydrological connection to surface water. Although the model links watershed inputs with embayment circulation and nitrogen characteristics, it conservatively assumes that nitrogen moves through groundwater and that nitrogen directly transported via groundwater enters the embayments. In short, the data and analysis provided, which supports the regional framework required for a TMDL, simply does not contain the type of data or level and scale of analysis that can support the site- and source-specific ecological determinations necessary to find that a discharge via groundwater has a direct and immediate hydrological connection to surface waters for any given source on Cape Cod. Therefore, MassDEP considered the pollutant loads discharged from septic systems and WWTFs discharging to soils to be nonpoint sources for purposes of the TMDL, and it allocated these sources to the LA.*

The effects of climate change on water quality have not been adequately addressed in this TMDL; a larger Margin of Safety should be considered in future TMDLs.

MassDEP Response: MassDEP recognizes that long-term climate change impacts to southeastern Massachusetts are occurring based on known science. However, the details of how climate change will affect future precipitation, streamflow, sediment and nutrient loading in specific locations are generally unknown. In light of the uncertainties, MassDEP has chosen to address the uncertainty of climate change through an implicit MOS (i.e., incorporated into the TMDL through conservative assumptions). Furthermore, TMDLs are developed and implemented with an adaptive management approach. MassDEP will address climate change issues more specifically through TMDL implementation, as warranted.

Eelgrass recovery targets may require lower nitrogen thresholds.

MassDEP Response: MassDEP agrees that a lower nitrogen concentration at the sentinel station may be required to observe habitat recovery. The goal of the TMDL for Megansett-Squeteague Harbors is to restore the estuary habitats first for eelgrass with a consequent improvement in the benthic infauna habitat and the target concentration of 0.35 mg/L at station MG-2 is the guide to getting there. If we reach the target concentration at the sentinel station but do not observe eelgrass habitat improvement, then the TMDL allows, through the process of Adaptive Management, a re-evaluation of the nitrogen reduction strategy and lowering of the target concentration. The threshold concentration is a target, but the final goal is habitat restoration. Proposed nitrogen reductions within the watershed should be fully implemented, prior to reevaluating sentinel station concentrations, particularly if habitat recovery is not observed. Establishing a revised target concentration and nitrogen reduction strategy will likely require additional modeling.

An implementation schedule and monitoring plan should be promptly developed.

MassDEP Response: MassDEP is working with the watershed towns for these TMDLs in developing or implementing Comprehensive Water Resources or Wastewater Management Plans (CWRMP or CWMP). Each of the towns is progressing and is at different stages in the process. Implementation plans and schedules are not required as part of the TMDL but are required in watershed permits and CWRMP/CWMPs. The Town of Bourne issued a request for proposal

(RFP) to develop a CWMP on December 30, 2019. Through the CWMP the town will incorporate the TMDL and develop an implementation schedule.

The Town of Falmouth was issued a certificate from the Massachusetts Policy Act office (MEPA) for a third Notice of Project Change (NPC) for the CWMP on February 7, 2020 (EEA #14154). The NPC "summarized data collected through water quality monitoring and reviewed the status and effectiveness of pilot projects, including shellfish aquaculture, permeable reactive barriers (PRBs), eco-toilets, I/A septic systems, adoption of a Nitrogen Control Bylaw for fertilizer, stormwater management and the Bournes Pond inlet widening project." The third NPC provided updates on the Target Watershed Management Plans (TWMP) for Falmouth's southern estuaries and West Falmouth Harbor. The goal of CWMP is to meet Surface Water Quality Standards through the achievement of the TMDLs.

General and Frequently Asked Questions:

1. **Can a Comprehensive Water Resources Management Plan (CWRMP) include the acquisition of open space, and if so, can State Revolving Funds (SRF) be used for this?**

MassDEP Response: State Revolving funds can be used for open space preservation if a specific watershed property has been identified as a critical implementation measure for meeting the TMDL. The SRF solicitation should identify the land acquisition as a high priority project for this purpose which would then make it eligible for the SRF funding list. However, it should be noted that preservation of open space will only address potential future nitrogen sources (as predicted in the build-out scenario in the MEP Technical report) and not the current situation. The town will still have to reduce existing nitrogen sources to meet the TMDL.

2. **Do we expect eelgrass to return if the nitrogen goal is higher than the concentration that can support eelgrass?**

MassDEP Response: There are a number of factors that can control the ability of eelgrass to re-establish in any area. Some are of a physical nature (such as boat traffic, water depth, or even sunlight penetration) and others are of a chemical nature like nitrogen. Eelgrass decline in general has been directly related to the impacts of eutrophication caused by elevated nitrogen concentrations. Therefore, if the nitrogen concentration is elevated enough to cause symptoms of eutrophication to occur, eelgrass growth will not be possible even if all other factors are controlled. The eelgrass will not return until the water quality conditions improve. Where there is no historical evidence of eelgrass, the target concentration has been set at a higher concentration than generally tolerated by eelgrass, with the goal of restoring the benthic habitat.

3. **Who is required to develop the CWRMP? Can it be written in-house if there is enough expertise?**

MassDEP Response: The CWRMP can be prepared by the town. There are no requirements that it must be written by an outside consultant; however, the community should be very confident that its in-house expertise is sufficient to address the myriad issues involved in the CWRMP process. MassDEP would strongly recommend that any community wishing to undertake this endeavor on its own should meet with MassDEP to develop an appropriate scope of work that will result in a robust and acceptable plan.

4. **Have others written regional CWRMPs (i.e. included several neighboring towns)?**

MassDEP Response: The Cape Cod Commission prepared a Regional Wastewater Management Plan or RWMP which formed a framework and set of tools for identifying several solutions for restoring water quality for each watershed on the Cape. The Section 208 Plan Update (or 208 Plan) is an area-wide water quality management plan and in general each town then prepared or is preparing its own CWRMP. An example of neighboring towns working on a regional plan is the Pleasant Bay Alliance which consists of Orleans, Brewster, Harwich, and Chatham. Harwich, Dennis and Yarmouth are in discussions regarding a shared wastewater treatment plant.

Joint Comprehensive Wastewater Management Plans (CWMPs) have been developed by multiple Towns particularly where Districts are formed for purposes of wastewater treatment. Some examples include the Upper Blackstone Water Pollution Abatement District that serve all or portions of the towns Holden, Millbury, Rutland West Boylston and the City of Worcester and the Greater Lawrence Sanitary District that serves the greater Lawrence area including portions of Andover, N. Andover, Methuen and Salem NH. There have also been recent cases where Towns have teamed up to develop a joint CWMP where districts have not been formed. The most recent example is the Towns which discharge to the Assabet River. They include the Towns of Westboro and Shrewsbury, Marlboro and Northborough, Hudson, and Maynard. The reason these towns joined forces was because as a group, they received more priority points in the State Revolving Fund application process than they otherwise would have as individual towns.

5. **Does nitrogen entering the system close to shore impair water quality more? If we have to sewer, wouldn't it make sense to sewer homes closer to the shore?**

MassDEP Response: Homes closer to the waterbody allow nitrogen to get to that waterbody faster (shorter travel times). Those further away may take longer but still get there over time and are dependent upon the underlying geology. However, what is more important is the density of homes. Larger home density means more nitrogen being discharged thus the density typically determines where to sewer to maximize reductions. Also, there are many factors that influence water quality such as flushing and morphology of the water body.

6. **Do you take into account how long it takes nitrogen in groundwater to travel to the estuaries?**

MassDEP Response: Yes, the MEP Technical report has identified long term (greater than 10 years) and short-term time of travel boundaries in the ground-watershed.

7. **What if a town can't meet its TMDL?**

MassDEP Response: A TMDL is simply a nutrient budget that determines how much nitrogen reduction is necessary to meet water quality goals as defined by state Water Quality Standards. It is unlikely that the TMDL cannot be achieved however in rare occasions it can happen. In those rare cases the Federal Clean Water Act provides an alternative mechanism which is called a Use Attainability Analysis (UAA). The requirements of that analysis are specified in the Clean Water Act but to generalize the process, it requires demonstration that the designated use cannot be achieved. In other words, demonstrate that the body of water cannot support its designated uses such as fishing, swimming or protection of aquatic biota. Demonstrating this is very difficult and must be approved by the U.S. Environmental Protection Agency. As long as a plan is developed and actions are being taken at a reasonable pace to achieve the goals of the TMDL, MassDEP will use discretion in taking enforcement steps. However, in the event that reasonable progress is not being made, MassDEP can take additional regulatory action through the broad authority granted by the Massachusetts Clean Waters Act, the Massachusetts Water Quality Standards, and through point source discharge permits and MS4 stormwater permits.

8. **What is the relationship between the linked model and the CWRMP?**

MassDEP Response: The model is a tool that was developed to assist the Town to evaluate potential nitrogen reduction options and determine if they meet the goals of the TMDL at the established sentinel station in each estuary. The CWRMP is the process used by the Town to evaluate your short and long-term needs, define options, and ultimately choose a recommended option and schedule for implementation that meets the goals of the TMDL. The models can be used to assist the Towns during the CWRMP process.

9. **Is there a federal mandate to reduce fertilizer use?**

MassDEP Response: No, it is up to the states and/or towns to address this issue. However, the Massachusetts Department of Agricultural Resources (MassDAR) passed plant nutrient regulations (330 CMR 31.00) in June 2015, which requires specific restrictions for agricultural and residential fertilizer use, including seasonal restrictions, on nutrient applications and set-backs from sensitive areas (public water supplies and surface water) and Nutrient Management Plans. Compliance with the MassDAR regulations will result in reductions in future N loading from agricultural sources.

10. Will monitoring continue at all stations or just the sentinel stations?

MassDEP Response: At a minimum, MassDEP would like to see monitoring continued at the sentinel stations bi-monthly, May-September in order to determine compliance with the TMDL. However, ideally, it would be good to continue monitoring all of the stations, if possible. The benthic stations can be sampled every ~5 years since changes are not rapid. The towns may want to sample additional locations if warranted. MassDEP intends to continue its program of eelgrass monitoring in cooperation with the Massachusetts Maritime Academy.

11. What is the state's expectation with CWRMPs?

MassDEP Response: The CWRMP is intended to provide the Towns with potential short and long-term options to achieve water quality goals and therefore provides a recommended plan and schedule for sewering/infrastructure improvements and other nitrogen reduction options necessary to achieve the TMDL. The state also provides a low interest loan program called the state revolving fund or SRF to help develop these plans. Towns can combine forces to save money when they develop their CWRMPs.

12. Can we submit parts of the plan as they are completed?

MassDEP Response: Submitting part of a plan is not recommended because absent a comprehensive plan, a demonstration cannot be made that the actions will meet the requirements of the TMDL. With that said however the plan can contain phases using an adaptive approach if determined to be reasonable and consistent with the TMDL.

13. How do we know the source of the bacteria (septic vs. cormorants, etc.)?

MassDEP Response: This was not addressed because this is a nitrogen TMDL and not a bacteria TMDL.

14. Is there a push to look at alternative new technologies?

MassDEP Response: MassDEP recommends communities consider all feasible alternatives to develop the most effective and efficient plans to meet water quality goals. The 208 Plan Update includes an analysis of a wide range of traditional and alternative approaches to nutrient reduction, remediation, and restoration. If a CWRMP relies on such alternative technologies and approaches, the plan must include demonstration protocols, including monitoring, that will confirm that the proposed reduction credits and, when appropriate, removal efficiencies are met. The implementation schedule is in the demonstration protocol for each alternative technology or approach, at which time a determination must be made as to whether the alternative technology/approach meets the intended efficacy goal. MassDEP is also developing Watershed Permits (or Targeted Watershed Management Plans), which includes but is not limited to Under

Ground Injection Control (UIC) and groundwater discharge permits and provides a permitting mechanism to approve nontraditional methods of wastewater management and/or impact mitigation that could not otherwise be approved by MassDEP under a typical wastewater management and discharge permit. Watershed permits include implementation timetables, standards to be achieved, and long-term monitoring to evaluate water quality improvements.

The Massachusetts Alternative Septic System Test Center, located on Cape Cod and operated by the Barnstable County Department of Health and Environment, tests and tracks advanced innovative and alternative septic system treatment technologies. In addition, MassDEP evaluates pilot studies for other alternative technologies; however, absent a CWRMP and Watershed Permit, MassDEP will not approve a system for general use unless it has been thoroughly studied and documented to be successful.

15. How about using shellfish to remediate and reduce nitrogen concentrations?

MassDEP Response: The use of shellfish to remediate and reduce nitrogen concentrations is an alternative approach that has been utilized and is being evaluated in some areas of Long Island Sound (LIS), Wellfleet, and Chesapeake Bays. More recently, some Cape communities have been evaluating this method, including Falmouth, Mashpee and Orleans. While this approach has demonstrated promise for reducing nitrogen concentrations, there remain questions regarding the effectiveness and circumstances where it can be successfully utilized. MassDEP recommends communities considering this option discuss such plans with the Department and evaluate the results from ongoing efforts on the Cape and on other states.

16. The TMDL is a maximum number, but we can still go lower.

MassDEP Response: The state's goal is to achieve designated uses and water quality criteria. There is nothing however that prevents a Town from implementing measures that go beyond that goal. It should also be noted that the TMDL is developed conservatively with a factor of safety included.

17. Isn't it going to take several years to reach the TMDL?

MassDEP Response: It is likely that several years will be necessary to achieve reductions and to see a corresponding response in the estuary. However, the longer it takes to implement solutions, the longer it is going to take to achieve the goals.

18. The TMDL is based on current land use but what about future development?

MassDEP Response: The TMDL is based on a habitat restoration target(s)for conditions during the period of data collection. Buildout was considered in the MEP model as part of scenario *runs to evaluate implementation strategies. Evaluation of buildout conditions must be considered as part of the CWMP.*

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Waquoit Bay, Falmouth Inner Harbor, Megansett and Squeteague Harbors Estuarine Systems

Nitrogen TMDL Public Meeting

	Print Name	Affiliation
1.	Tom Duncan	FALMOUTH WASTEWATER MGMT. COMM
2.	Kristen Rathjen	Science Wares
3.	Eric Turkington	Falmouth WQMC
4.	Jeff Gregg	GHD INC.
5.	Virginia Valiela	Falmouth WQMC
6.	Stephen Leighton	" "
7.	PETER FANG	Falmouth Water Stewards
8.	Rachel Jakuba	Buzzards Bay Coalition
9.	Korrin Petersen	"
10.	LAURA BLAKE	MASS DEP
11.	Barbara Kickham	Mass DEP
12.	Drew Osei	Mass DEP

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Nitrogen TMDL Public Meeting

	Print Name	Affiliation
13.	Brian Dudley	Mass DEP
14.	Ed Eichner	TMDL Solutions
15.	Brian Howes	SMAST - UMD
16.	Amy Lowell	Town - Wastewater Div
17.	Paul Dreyer	Fal Planning Board
18.	Patti Kellogg	MassDEP
19		
20.		
21.		
22.		
23.		