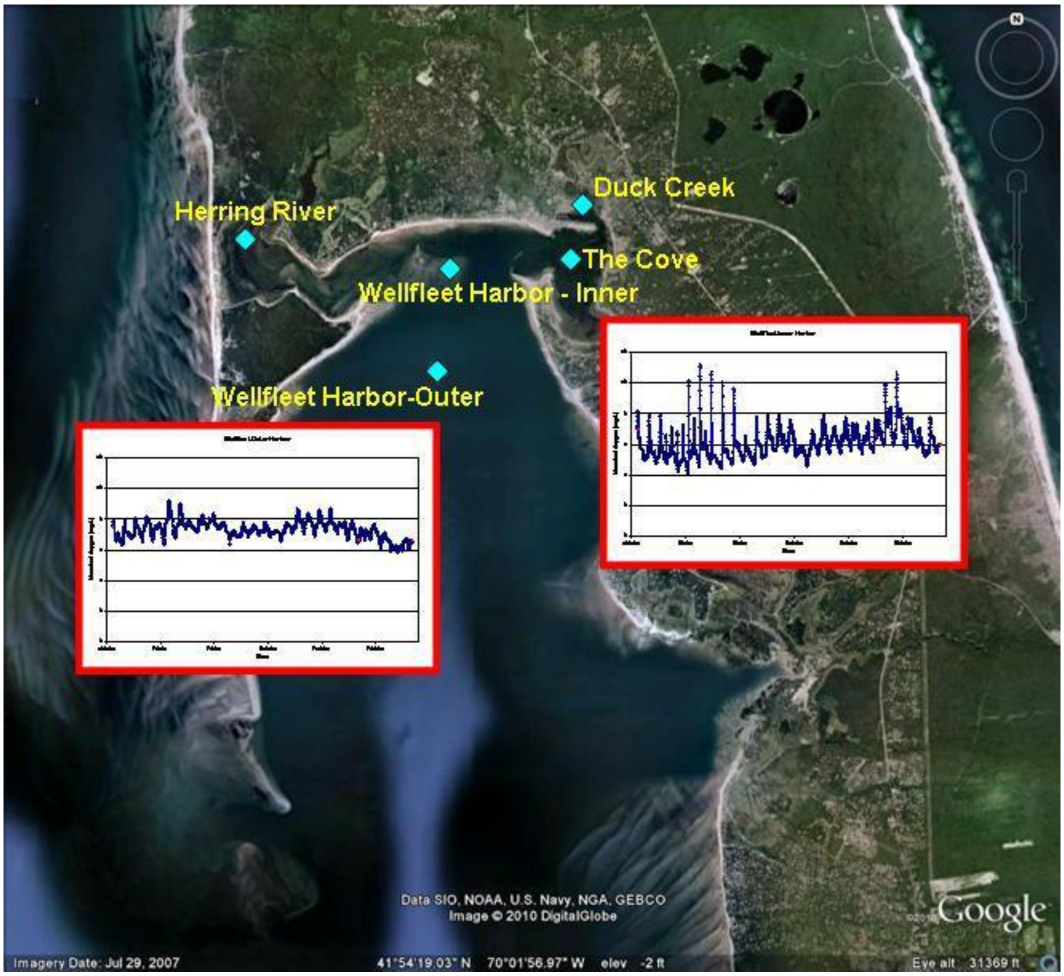
Draft Wellfleet Harbor Embayment System
Town of Wellfleet, Massachusetts
Total Maximum Daily Load
For Total Nitrogen
(CN # 447.0)



COMMONWEALTH OF MASSACHUSETTS
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June 2022

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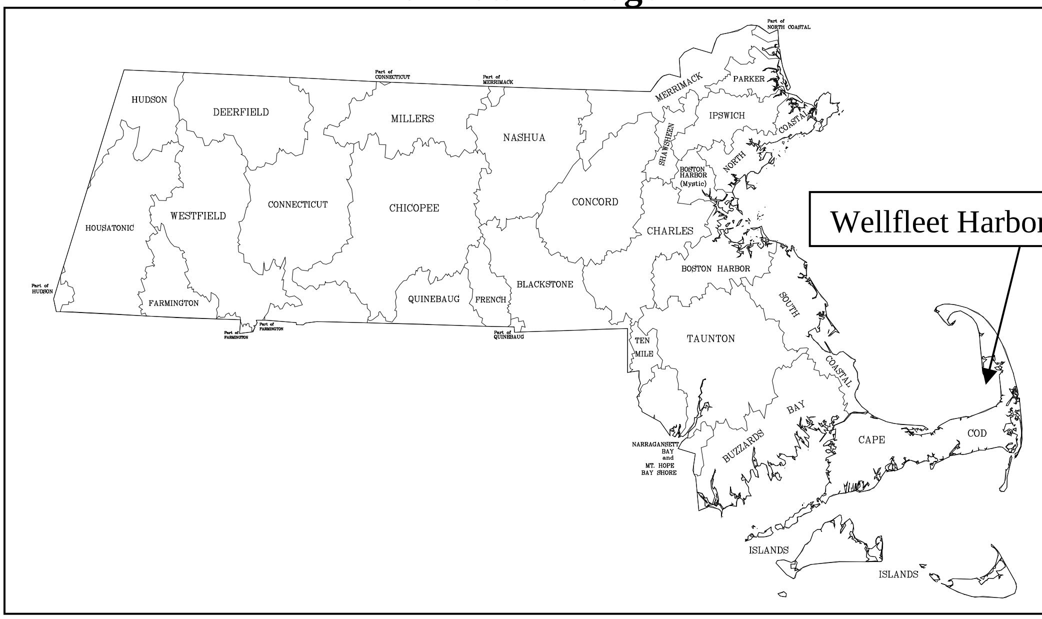

Key Feature: Total Nitrogen TMDL for Wellfleet Harbor Embayment System

Location: EPA Region 1**,** Towns of Wellfleet, Truro and Eastham, MA

Land Type: New England Coastal

303d Listing: **2018/2020 Integrated List:** Wellfleet Harbor (MA96-34) (Category 5), Nutrient/Eutrophication Biological Indicators, Total Nitrogen. Herring River (MA96-33) (Category 5) Aluminum, Estuarine Bioassessments, Fish Passage Barrier, and Flow Regime Alterations, Low pH. Duck Creek (MA96-32) (Category 5) Benthic Macroinvertebrates, Dissolved Oxygen, Total Nitrogen, Nutrient/Eutrophication Biological Indicators. Loagy Bay (MA96-125) Chlorophyll *a*, Dissolved Oxygen. Duck Creek and Herring River have approved TMDLs for Fecal Coliform.

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 Wellfleet; Town of Truro, Cape Cod National Seashore

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

Monitoring Plan: Cape Cod Commission/Town of Wellfleet, Town of Truro, Cape Cod National Seashore, with technical assistance by SMAST

Control Measures: Sewering, Storm Water Management, Fertilizer Use By-laws

Executive Summary

Problem Statement

Excessive nitrogen (N) originating from a variety of sources has added to the impairment of the environmental quality of Wellfleet Harbor. In general, excessive N in these waters is indicated by:

- Undesirable increases in macro-algae;
- Periodic decreases in dissolved oxygen concentrations that threaten aquatic life;
- Reductions in the diversity of benthic animal populations;
- Periodic algae blooms.
- Eelgrass loss

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

- Periodic fish kills or algae blooms;
- 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 Wellfleet, Truro and Eastham, 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 lead to possible increases in macro-algae, a higher frequency of undesirable 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 system. As a result of these environmental impacts, commercial and recreational uses of the Wellfleet Harbor estuarine system could be greatly reduced.

Sources of Nitrogen

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

- The watershed
    - on-site subsurface wastewater disposal (septic) systems
    - runoff from impervious surfaces
    - fertilizers
    - wastewater treatment facilities (WWTF)
    - landfills
    - agricultural activities
    - natural background
- Atmospheric deposition
- Nutrient-rich bottom sediments in the embayments/ponds

Figure ES-A below indicates the percent contributions of the various sources of N in the watershed to Wellfleet Harbor. Values are based on Table ES-1 and Table 3 from the Massachusetts Estuaries

Project (MEP) Technical Report (Howes *et. al*, 2017). As evident from this figure, most of the controllable N load to Wellfleet Harbor originates from septic systems.

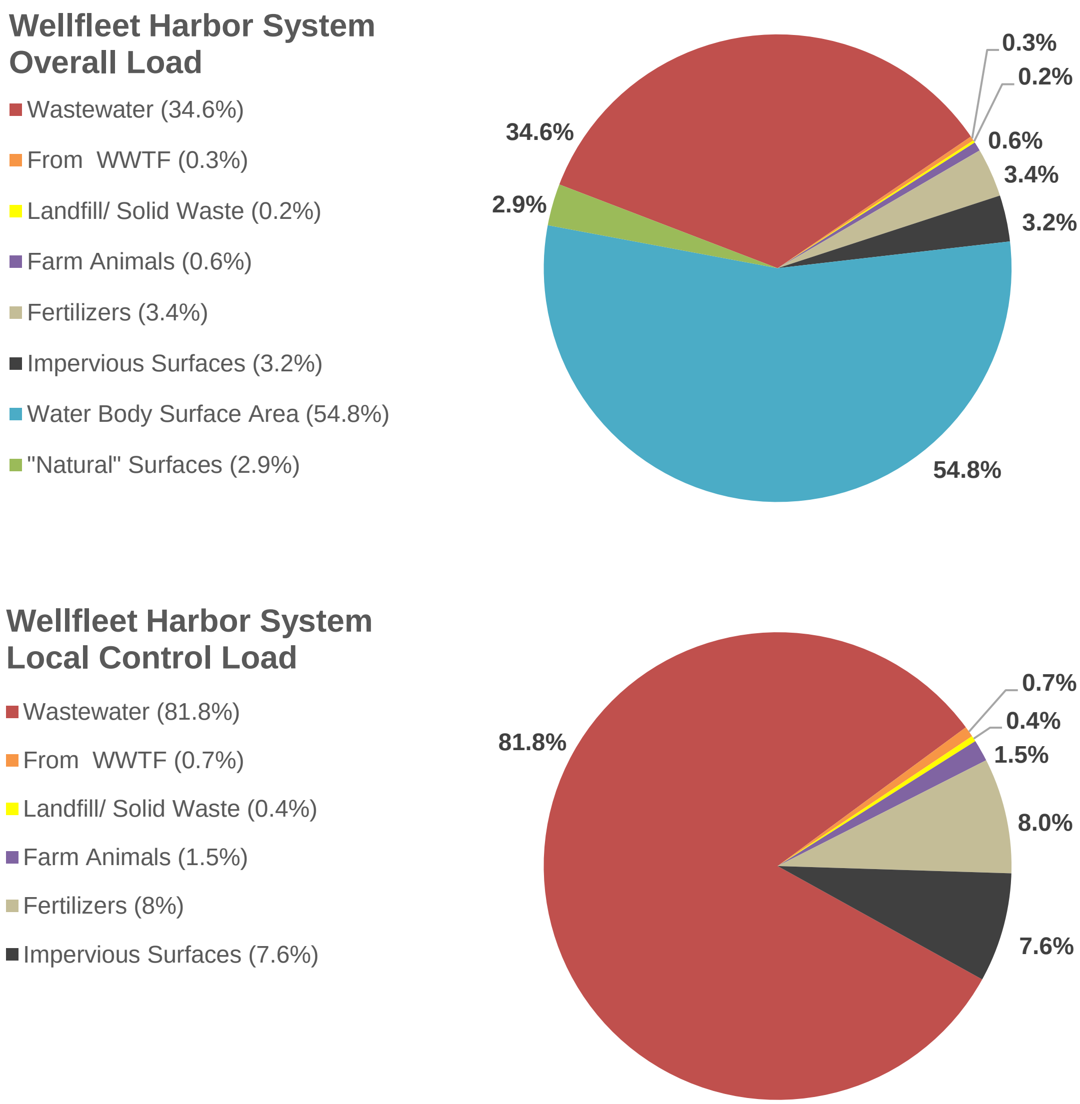

Figure ES-A: Percent Contributions of All Watershed Nitrogen Sources and Percent Contributions of Nitrogen Sources to Wellfleet Harbor

Target Threshold Nitrogen Concentrations and Loadings

The Wellfleet Harbor embayment system is located within the Town of Wellfleet on Cape Cod in Massachusetts. The system has a western shore bounded by a narrow barrier beach (the Gut extending southward past Great Island and ending at Jeremy Point) separating the Harbor from Cape Cod Bay, with which it exchanges tidal waters. The Wellfleet Harbor Estuary is one of the largest embayments on Cape Cod and is comprised of large open water areas (namely Wellfleet Harbor) as well as small tributary sub-embayments such as the mouth of Herring River at The Gut, Duck Creek, The Cove, Drummers Cove and Loagy Bay. The watershed contributing nitrogen to the waters of the Wellfleet Harbor Estuary is contained primarily within the Town of Wellfleet except for smaller watershed areas within Truro and Eastham.

The present total attenuated watershed nitrogen load that enters the estuary each day (N load) is 79.74 kg/day from the combined subwatersheds (Table ES-1, MEP Technical Report, Howes *et al*, 2017). The resultant annual average concentration of N was 0.655 mg/L (average of yearly means at the 12 stations collected from 2003 – 2011 as reported in Table VI-1 of the MEP Technical Report and included in Appendix B of this report).

In order to restore and protect this estuarine system, 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*. The goal of the TMDL is to reach this target threshold N concentration, as it has been determined for each impaired waterbody segment. The MEP has determined that an N concentration of 0.53 mg/L for this estuarine system at the sentinel station in upper Wellfleet Harbor (WH-5) will restore benthic habitat for infauna animals in the main harbor.

Based on sampling and modeling analysis and the resulting Technical Report, the MEP has determined that the Total Maximum Daily Load (TMDL) of N to meet the target threshold N concentration of 0.53 mg/L is 357.17 kg N/day (with negative benthic flux set to zero) for the main Wellfleet Harbor system. The mechanism for achieving these target threshold N concentrations is to reduce the N loadings to the Wellfleet Harbor system. To meet the TMDL, this report suggests that a 31.4% reduction of the total watershed nitrogen load for the entire system will be required.

The restoration target for the mouth of the Herring River (MA96-33) is for eelgrass habitat due to the historical evidence of eelgrass in this waterbody segment in 1995 and 2001 (MassGIS, 2018). The Herring River Restoration Project will result in major improvements in tidal exchange and flushing (Herring River Restoration Committee, 2007). This project is expected to improve water quality to meet Massachusetts Surface Water Quality Standards (SQWS) and restore eelgrass habitat. Additional data analysis and modeling is needed to demonstrate that the Herring River Restoration Project will serve as an Alternative Restoration Project for the mouth of the Herring River. An Alternative Restoration Project, also referred to as an Adaptive Resource Management Strategy, requires that the waterbody remain in Category 5, Waters Requiring a TMDL in the Integrated List of Waters, until SWQS are met or until a traditional TMDL is completed.

This document presents the total nitrogen (TN) TMDL required for benthic habitat restoration for this water body and provides guidance to towns of Wellfleet, Truro and Eastham on possible ways to reduce the N loadings to within the recommended TMDL and protect the waters of this estuarine system.

Implementation

The primary goal of the TMDL implementation will be lowering the concentrations of N in the Wellfleet Harbor Embayment System. The MEP linked model has shown that by reducing the loadings from on-site subsurface wastewater disposal systems in the watershed by up to 85%, the target threshold concentration 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.

The Herring River Restoration Project involves replacing the Chequessett Dike Dam with a bridge and a control structure to allow managed increases in tidal flow and exchange with Wellfleet Harbor. Upper Pole Road will be raised and a larger culvert installed with an attached tide gate to manage water levels locally, separate from the main system, to avoid unanticipated flooding or changes to local hydrology. Similarly, a dike at Mill Creek will be constructed to manage water levels locally, separate from the main system.

In addition to modeling current conditions and necessary nitrogen reductions, the MEP project also coordinated with the Town of Wellfleet to conduct an alternative model run based on the town's interim 2030 development forecast and refinements. This scenario did not look at land classification, but rather evaluated housing and populations trends. This analysis of future project development completed by the Town CWMP committee resulted in 131 new dwelling units in Wellfleet at 2030, as compared to MEP estimate of 1,517 new dwelling units based on development of all available properties according to current zoning. Based on the alternative buildout assessment, buildout additions within the Wellfleet Harbor watersheds will increase the unattenuated watershed nitrogen loading rate by 3% (compare to 32% increase estimated for full build out).

Local officials can explore other load 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 loading from septic systems, stormwater runoff and fertilizers are provided in detail in the "MEP Embayment Restoration and Guidance for Implementation Strategies", available on the MassDEP website: https://www.mass.gov/doc/embayment-restoration-and-guidance-for-implementation-strategies. 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 towns of Wellfleet, Truro and Eastham which would exacerbate the problems associated with N loading, 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 of Wellfleet, Truro and Eastham to develop specific implementation strategies to reduce nitrogen (N) loadings and will assist in developing a monitoring plan for assessing the success of the nutrient reduction strategies.

In the Wellfleet Harbor estuarine system, the pollutant of concern for this TMDL (based on observations of eutrophication) is the nutrient nitrogen. Since nitrogen is the limiting nutrient in coastal and marine waters, as its concentration increases, so does plant productivity. This leads to nuisance populations of macro-algae and increased concentrations of phytoplankton and epiphyton that imperil the healthy ecology of the affected water bodies.

The TMDL for total N for the Wellfleet Harbor system is based primarily on data collected, compiled and analyzed by University of Massachusetts Dartmouth's School for Marine Science and Technology (SMAST), the Cape Cod Commission, the Town of Wellfleet Water Quality Monitoring Program and others, as part of the Massachusetts Estuaries Project (MEP). The data were collected over a study period from 2003 to 2011. This study period will be referred to as the "Present Conditions" in the TMDL since it contains the most recent data available. The MEP Technical Report can be found on the MassDEP website and at https://www.mass.gov/guides/the-massachusetts-estuaries-project-and-reports. The MEP Technical Report presents the results of the analyses of this coastal embayment system using the MEP Linked Watershed-Embayment Nitrogen Management Model (Linked Model).

The analyses were performed to assist Wellfleet 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 on this embayment. These assessments served as the basis for generating a N loading threshold for use as a goal for watershed N management. The TMDL is 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 Wellfleet, Truro and Eastham.

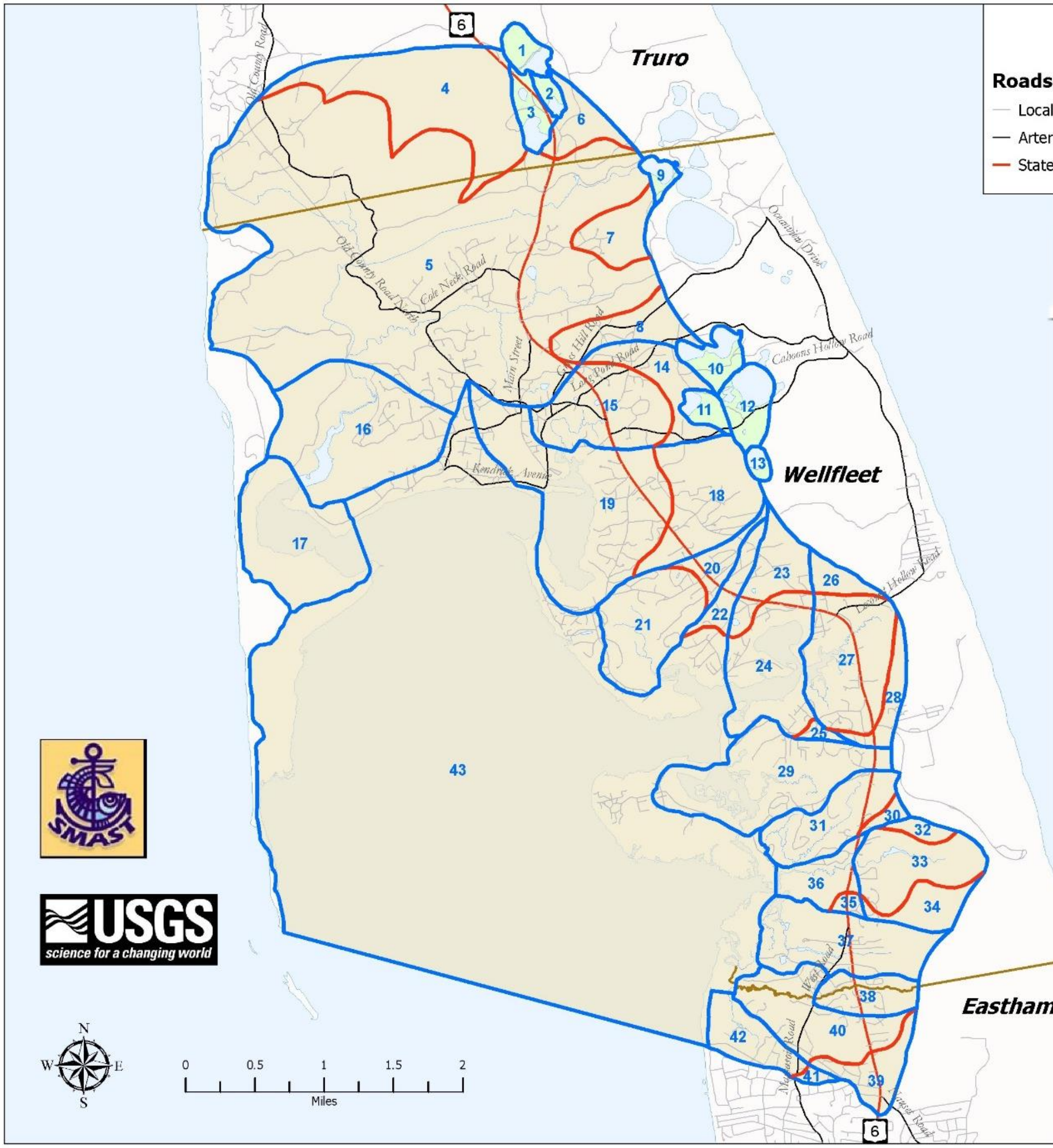
Description of Water Bodies and Priority Ranking

The Wellfleet Harbor embayment system is located within the Town of Wellfleet on Cape Cod in Massachusetts. The system has a western shore bounded by a narrow barrier beach (the Gut extending southward past Great Island and ending at Jeremy Point) separating the Harbor from Cape Cod Bay, with which it exchanges tidal waters. The Wellfleet Harbor Estuary is one of the largest embayments on Cape Cod and is comprised of large open water areas (namely Wellfleet Harbor) as well as small tributary sub-embayments such as the mouth of Herring River at The Gut, Duck Creek, The Cove, Drummers Cove and Loagy Bay (Figure 1). The watershed contributing nitrogen to the waters of the Wellfleet Harbor Estuary is contained primarily within the Town of Wellfleet except for smaller watershed areas in Truro and Eastham. The uppermost portion of the Bound Brook sub-watershed extends into the Town of Truro. Restoration of degraded habitats within the estuary system will depend mainly upon the efforts of the Town of Wellfleet and its citizens, however, depending on the level of nutrient management there may be the need for some coordination of efforts with the towns of Truro and Eastham. In addition, the National Seashore manages land within the watershed, but for the most part these areas are undeveloped and contribute little nitrogen load to the estuary.

Figure 1: Overview of Wellfleet Harbor

The MEP team has delineated a watershed, land surface area of approximately 11,312 acres for the Wellfleet Harbor system. The delineated contributory watershed includes 43 subwatersheds which were delineated for estimation of groundwater flows and nutrient export (Figure 2, Howes *et. al*, 2017, pg. 31). The MEP team has estimated a total groundwater flow for the system of 75,022 m^3/day.

In the overall Wellfleet Harbor watershed, the predominant land use based on area is public service land use, which accounts for 52% of the overall watershed area while residential land use represents the second highest percentage (29%) of watershed area (Howes *et. al* 2017, pg. 38). Undeveloped lands account for 7% of the entire Wellfleet Harbor watershed area.



SHED_ID	SHED_NAME
1	Great Pond Truro
2	Snow Pond
3	Ryder Pond
4	High Toss GT10 N
5	High Toss LT10
6	High Toss GT10 NE
7	High Toss GT10 E
8	High Toss GT10 SE
9	Herring Pond
10	Long Pond
11	Dyer Pond
12	Great Pond Wellfleet
13	Duck Pond
14	Duck Creek GT10
15	Duck Creek LT10
16	Herring River
17	The Gut
18	The Cove GT10
19	The Cove LT10
20	Pilgrim Spring GT10
21	Pilgrim Spring LT10
22	Wellfleet Harbor GT10
23	Drummer Cover GT10 N
24	Drummer Cover LT10
25	Drummer Cover GT10 S
26	Blackfish Creek GT10 N
27	Blackfish Creek LT10
28	Blackfish Creek GT10 S
29	Loagy Bay
30	Trout Brook GT10
31	Trout Brook LT10
32	Upper Fresh Brook GT10 N
33	Upper Fresh Brook LT10
34	Upper Fresh Brook GT10 S
35	Lower Fresh Brook GT10
36	Lower Fresh Brook LT10
37	Silver Spring Brook
38	Hatches Creek Gauge
39	Hatches Creek GT10
40	Hatches Creek LT10
41	Sunken Meadow GT10
42	Sunken Meadow LT10
43	Wellfleet Harbor LT10

Figure 2: Wellfleet Harbor Watershed Area Delineation (Howes *et. al* 2017, pg. 31)

A more complete description of this estuarine system is presented in Chapters I and IV of the MEP Technical Report (Howes *et. al* 2017). Most of the information presented here regarding this estuarine system is drawn from the Technical Report. Chapters VI and VII of the MEP Technical Report provide assessment data that show that the Wellfleet Harbor estuarine system is impaired due to excess nutrients, low dissolved oxygen levels, elevated chlorophyll *a* levels, and benthic fauna habitat degradation.

The nature of enclosed embayments in populous regions brings two opposing elements to bear: 1) as protected marine shoreline they are popular regions for boating, recreation, and land development and 2) as enclosed bodies of water, they may not be readily flushed of the pollutants that they receive due to the proximity and density of development near and along their shores. The Wellfleet Harbor system is at risk of further eutrophication from high nutrient loads in the groundwater and runoff from the watershed.

While Wellfleet Harbor presently has a relatively low nitrogen load from its watershed, due to its moderately sized watershed and proportionally large undeveloped areas, it is still showing signs of impairment by nitrogen enrichment in the upper most reaches of the system (tributary basins) and is clearly eutrophic (e.g., Duck Creek). Overall, the estuary is showing some nitrogen related habitat impairment within some of its component basins, however, most of the system is supporting high quality to moderately impaired habitat, with regions of moderate to significant impairment found only in Duck Creek, which was significantly nitrogen enriched (0.93 mg/L tidally averaged TN) and is furthest from the systems tidal inlet. As such, nutrient management in the Wellfleet Harbor watershed is warranted. This information was used to list Duck Creek (MA96-32) as impaired (Category 5) for benthic macroinvertebrates, dissolved oxygen, total nitrogen, nutrient/eutrophication biological indicators.

Herring River (MA96-33) is impaired (Category 5) and has been listed as impaired upstream from the dike at Chequessett Neck (the upper 0.071 mi^2 area) because of flow alterations (changes in tidal amplitude and flushing) and fish-passage barrier, both of which are non-pollutants and do not require a TMDL. Herring River is also impaired for pollutants including low pH conditions, associated metals toxicity due to the lowering of the water table in the marsh sediments (aluminum), estuarine bioassessments, and fecal coliform. Due to the presence of the Chequessett Neck Dike, the river is primarily fresh water, instead of marine water as it would be in its natural state. Prior to construction of the dikes (Chequessett Neck, Pole Dike, and Mill Creek Dike) the Herring River was a complex system that included estuary in the lower reaches, salt marsh, and brackish-to-fresh water marshes. Historically Herring River was bordered by nearly 1,100 acres of saltwater marsh (Herring River Technical Committee, 2007).

Herring River (MA96-33) and Duck Creek (MA96-32) both have an approved TMDL for fecal coliform, CN 252.0, EPA TMDL #36772 (MassDEP 2009).

Wellfleet Harbor currently supports relatively healthy habitat, however, it appears to be beyond its ability to assimilate additional nutrients without impacting ecological health. The tributary creeks, shallow basins and lagoons show impairment. The Wellfleet Harbor system is at risk of further eutrophication from high nutrient loads in the groundwater and runoff from the watershed. Wellfleet Harbor (MA96-34) has an approved TMDL for fecal coliform and was subsequently delisted for fecal coliform in the 2012 Integrated Report (MassDEP 2013). During the course of the MEP study, the harbor has been found to be impaired for nutrients, low dissolved oxygen, elevated chlorophyll *a*, and degradation of benthic infauna habitat (Table 1). Wellfleet Harbor (MA-96) is listed as impaired (Category 5) for total nitrogen and nutrient/eutrophication biological indicators, and Loagy Bay (MA96-125) is listed (Category 5) for chlorophyll *a* and low dissolved oxygen. Although Wellfleet Harbor system is showing signs of nutrient impairment, nearly the entire harbor is approved for shellfish harvest.

Table 1: Comparison of DEP and SMAST Impaired Parameters for Wellfleet Harbor System

System Component	MassDEP Waterbody Segment ID	MassDEP Segment Description	Class	2018/2020 Integrated List (Category)	SMAST Impaired Parameter[1]	Size (Sq. Miles)[2]
Wellfleet Harbor**	MA96-34	The waters north of an imaginary line drawn east from the southern tip of Jeremy Point, Wellfleet to Sunken Meadow, Eastham excluding the estuaries of Herring River, Duck Creek, Blackfish Creek, and Fresh Brook, Wellfleet (area within Cape Cod National Seashore designated as ORW).	SA (ORW SFO)	-Nutrient/ Eutrophication Biological Indicators (5) -Nitrogen, Total (5)	Nutrients, Dissolved Oxygen, Chlorophyll *a*, Benthic Fauna	9.16
Herring River	MA96-33	South of High Toss Road, Wellfleet to mouth at inlet Wellfleet Harbor (at an imaginary line drawn due north from the eastern tip of Great Island to the opposite shore),	SA	-Estuarine Bioassessments -Aluminum, pH(5) -Low, Fish-Passage Barrier*(5) - Fecal Coliform (4A)[CN 252.0; EPA TMDL #36772]	Nutrients, Dissolved Oxygen, Chlorophyll *a*	0.4
Duck Creek	MA96-32	From Cannon Hill to Shirttail Point, Wellfleet.	SA	-Benthic Macroinvertebrates (5) -Dissolved Oxygen (5) -Nitrogen, Total -Nutrient/ Eutrophication Biological Indicators (5) -Fecal Coliform (4A) [CN 252.0; EPA TMDL #36772]	Nutrients, Dissolved Oxygen, Chlorophyll *a*, Benthic Fauna	0.15
Blackfish Creek	MA96-123	Headwaters south of Lecount Hollow Road, Wellfleet to mouth at confluence with Wellfleet Harbor, Wellfleet.	SA (SFO)	Insufficient information to assess (3)		0.01

System Component	MassDEP Waterbody Segment ID	MassDEP Segment Description	Class	2018/2020 Integrated List (Category)	SMAST Impaired Parameter[1]	Size (Sq. Miles)[2]
Fresh Brook	MA96-126	Estuarine portion west of Route 6, Wellfleet to mouth at confluence with Wellfleet Harbor, Wellfleet.	SA (SFO)	Insufficient information to assess (3)		0.004
Hatches Creek	MA96-124	Estuarine portion west of West Street, at the Wellfleet/Eastham border to mouth at confluence with Wellfleet Harbor, Wellfleet.	SA (SFO)	Insufficient information to assess (3)		0.02
Loagy Bay	MA96-125	Wellfleet.	SA (SFO)	Chlorophyll *a* (5) -Dissolved Oxygen (5)		0.2

* Non-pollutant, does not require TMDL
** Note includes portions of "The Cove" and Drummers Cove.
[1] As determined by the MEP Wellfleet Harbor Study and reported in the Technical Report, Howes *et al*, 2017.
[2] Sizes based on MassDEP Segments

<u>Priority Ranking</u>

The embayment addressed by this TMDL is determined to be a high priority based on three significant factors: (1) the initiative that the town has taken to assess the conditions of the entire estuarine system; (2) the commitment made by the town to restore and preserve the embayment; and (3) the extent of impairment in the embayment. This embayment is at risk of further degradation from increased N loads entering through groundwater and surface water runoff from the increasingly developed watershed. 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 Table 1, the Problem Assessment section below, and detailed in Chapter VII- Assessment of Embayment Nutrient Related Ecological Health of the MEP Technical Report.

Description of Hydrodynamics of the Wellfleet Harbor System

Wellfleet Harbor is an open embayment with a broad inlet to Cape Cod Bay. The lowest elevations of the system exist in the natural channel of the main harbor basin, where maximum depths of approximately -24 feet NAVD occur. The total surface coverage of the Wellfleet Harbor system is approximately 6,800 total acres, not including the area impounded by the Herring River dam.

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. Tide data records were collected concurrently at five gauging stations located at the opening to Cape Cod Bay (W-1), in Blackfish Creek (W-2), at the town pier in The Cove (W-3), Duck Creek upstream of Uncle Tim's Bridge (W-4) and downstream of the Herring Creek dam (W-5) (see Figure 5). The Temperature Depth Recorders (TDR) used to record the tide data were deployed for a 61-day period between August 24 and October 24, 2005. In addition, the phase delay of the main tidal constituent (lunar, twice per day tide, i.e. M2) was one and one-half hours at Uncle Tim's Bridge station. The computed flushing rates for the entire system show that the system flushes very well. A flushing time of 0.4 days for the entire estuary shows that on average, water is resident in the system for less than one day. For the smaller sub-embayments of the Wellfleet Harbor system, computed system residence times are typically two orders of magnitude longer than their corresponding local residence time. Tidal exchange with Cape Cod Bay dominates circulation in the Harbor (Howes *et. al* 2017).

Problem Assessment

The Town of Wellfleet which compromises most of the watershed area in the TMDL study area has been steadily growing over the past several decades (Figure 3). It is generally recognized that declines in water and habitat quality often parallel population growth in the watershed. Water quality problems associated with this development result primarily from on-site wastewater treatment systems and to a lesser extent from fertilizers and runoff from these developed areas. At the time of the data collection 100% of the parcels in the Wellfleet Harbor watershed relied on privately maintained septic systems for on-site treatment and disposal of wastewater. In addition, the nitrogen load from Harborside Trailer Park was included, with a groundwater discharge permit and an average annual flow of 7,525 gpd.

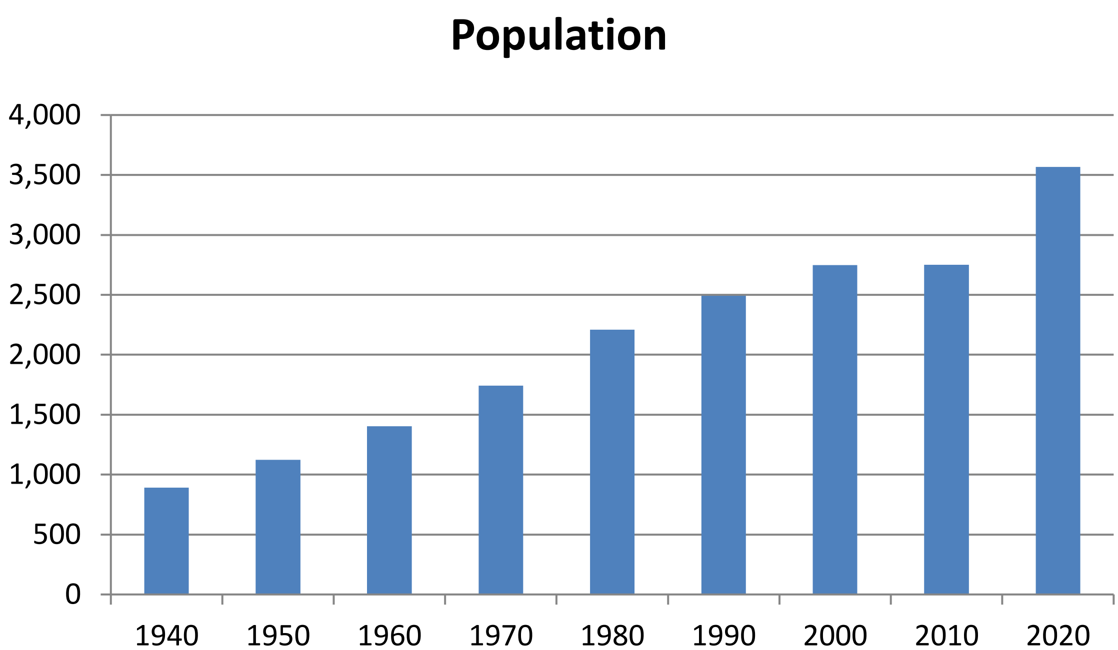


Figure 3: Wellfleet Historic Residential Population (US Census)

Coastal communities, including Wellfleet, 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 this coastal embayment, as described above, could significantly reduce the recreational and commercial value and use of these important environmental resources.

The primary ecological threat to Wellfleet Harbor is degradation resulting from nutrient enrichment. Most of the total N load (82%) is from septic systems, with other “controllable” N contributions coming from runoff of impervious surfaces and fertilizers. Other sources that are not locally controllable include atmospheric deposition to the surface of the estuary and natural surfaces. Nitrogen from these sources enters the groundwater and eventually enters the estuary system.

The Wellfleet Harbor Estuary is a complex estuary composed of three functional types of basins: shallow open water basins, shallow basins with significant associated salt marsh and a large estuarine lagoon (main basin) with high tidal velocities and areas of shifting sands (near inlet). Each of these basin types has differences in their natural sensitivity to nitrogen enrichment and organic matter loading and each has its own benthic community indicative of unimpaired or impaired habitat. None of these basins has historically supported significant eelgrass beds.

Measured dissolved oxygen depletion from moored sensors and grab samples indicate that much of the Wellfleet Harbor Estuary (e.g., Wellfleet-inner, The Cove, Duck Creek, Herring River, Drummers Cove/Loagy Bay and basin south of Lieutenants Island), except for the lower main basin of Wellfleet Harbor, are exhibiting moderate to significant oxygen stress (Table 2). Large daily oxygen excursions were recorded, indicative of nitrogen enrichment.

The MEP project reported Herring River (MA96-34) displayed periodic hypoxia, elevated chlorophyll *a* and, although the benthic community was largely healthy for a wetland basin, it showed a moderate level of impairment. MassDEP eelgrass mapping indicates the presence of eelgrass in Herring River in historical records from 1951 and the presence of small areas of eelgrass in 2001 MassDEP eelgrass survey (MassGIS, 2018). Only the lower reach of the Herring River, below the dike, is functioning as the lower reach of a wetland dominated tidal river (0.4 sq mi.). The benthic communities in such basins are typically adapted to the conditions, as can be seen in this case where there are a moderate to high number of species (18), low to moderate numbers of individuals in a community with high diversity (2.7) and evenness (>0.7). The benthic community is consistent with high quality habitat in a wetland type basin.

The MEP project found generally high oxygen levels and low to moderate levels of chlorophyll *a* in the Upper and Lower Main Harbor (Table 2). The MEP project found healthy to moderately impaired benthic community in the upper main basin while benthic metrics in the lower main basin were found to be driven by physical disturbance (unstable, swept medium coarse sands). In Wellfleet Harbor south of Lieutenant Island, the benthic community had high numbers of species (18) and individuals (1,079) but low diversity (1.18) and evenness (0.28) that is indicative of some impairment. The dissolved oxygen and chlorophyll *a* levels in Wellfleet Harbor were characterized by the MEP project as healthy with dissolved oxygen greater than 5 mg/L in over 95% of samples taken and moderate levels of chlorophyll (average approximately 6 ug/L) and with blooms found to be rare. Eelgrass has not been present in the main Wellfleet Harbor, however, eelgrass was mapped in 1995 and 2001 in the mouth of the Herring River.

Table 2: General Summary of Conditions Related to the Major Indicators of Habitat Impairment Observed in the Wellfleet Harbor System (excerpted Howes *et. al*. 2017, pg. 153)[1]

Wellfleet Harbor System Embayment	Dissolved Oxygen	Chlorophyll *a*[2]	Macroalgae	Benthic Fauna[2]	Overall
Upper Main Harbor	oxygen levels in Mid/Upper Main Basin were generally >5mg/L 97% of WQMP samples and >6mg/L mooring (99% record); uppermost main basin >5mg/L 96% of WQMP and >5 mg/L (mooring 90% record), DO almost always > 5mg/L. **[H]**	low-moderate chlorophyll *a* levels, WQMP average 6-7 ug/L, consistent with mooring record of <10ug/L 99% and >5 ug/L 13%-42% of record, averaging 3.5-5.0 ug/L over deployment**. [H]**	drift algae sparse or absent, little surface macrophyte mat, no visible accumulations	in the low velocity areas associated with the upper basin showed high quality habitat with a moderate number of species (12) and moderate numbers of individuals (277) individuals/grab), moderate diversity (2.09) and low evenness (0.60). **[H/MI]**	assessment based on impairment of benthic communities showing low-moderate impairment: moderate-high number of species with low-moderate individuals, moderate diversity and low evenness, with high oxygen and low chlorophyll a levels **[H/MI]**
Lower Main Harbor	oxygen levels in Lower Main Basin were >5mg/L 98% of WQMP samples, >6 mg/L (87% of samples). **[H]**	low-moderate chlorophyll *a* levels, WQMP average <6 ug/L **[H]**	drift algae sparse or absent, little surface microphyte mat, no visible accumulations	similar communities were in lower basin near the inlet as in upper main basin, area appears to be unstable with swept medium-coarse sands, consistent with the low-moderate number of individuals (83) and species (9), but high diversity (2.7) and evenness (0.8), similar to Chatham Harbor near inlet where high velocities created shifting sands & low benthic production**.[H]**	assessment based on impairment of benthic communities in high oxygen/low chlorophyll *a* waters showing only natural impairment by high velocity flows **[H]**
Duck Creek	mooring <5mg/L 38% of record, frequently <4 mg/L, with periodic declines to <3 mg/L, WQMP <4 mg/L and <3 mg/L (12% and 1% of samples, respectively). **[MI/SI]**	moderate chlorophyll *a*, WQMP average 8 ug/L, mooring average, 9 ug/L with periodic blooms to 14 ug/L **[MI]**	moderate accumulations of drift algae, Ulva, patchy with some areas with coverages of 75% [**MI]**	low number of species (9) and individuals (<100) with moderate diversity (2.09), with the small polychaete, *Streblospio*, dominating this basin consistent with an impaired benthic habitat **[MI-SI]**	assessment based on moderate-significant impairment of benthic communities (low number of species and individuals, with moderate diversity) with periodic hypoxia, macroalgal accumulations, high chlorophyll **[MI/SI]**

Wellfleet Harbor System Embayment	Dissolved Oxygen	Chlorophyll *a*[2]	Macroalgae	Benthic Fauna[2]	Overall
The Cove	mooring <5mg/L 10% of record, periodic declines to <4 mg/L, WQMP <4 mg/L, only >6 mg/L 47% of record and 26% of WQMP samples. **[MI/SI]**	moderate chlorophyll *a* levels, average 11 ug/L, with blooms typically 15-20 ug/L; WQMP average ~7 ug/L **[MI]**	drift algae sparse or absent, little surface microphyte mat, no visible accumulations	moderate number of species (9), low to moderate number of individuals (164), with low diversity (1.43) and evenness (0.45), consistent with the observed community dominated by amphipods (*Ampelisca abdita*), a transitional species (>80% of the community). Amphipods are an initial recovery species frequently found in high numbers and can form mats in areas of moderate to high organic matter enrichment **[MI]**	assessment based on moderate impairment of benthic communities (moderate number of species and individuals, with low diversity and evenness) with periodic hypoxia, high chlorophyll **[MI]**
Herring River Mouth	oxygen frequently <5mg/L and <4 mg/L, 35% and 12% of record, respectively, similarly <5mg/L 34% of WQMP samples and <4 mg/L 10% of 78 samples, may be result of receiving outflow from a large wetland. **[H/MI]**	moderate chlorophyll *a* levels, average 12 ug/L, with blooms typically 15-20 ug/L; WQMP average 6-8 ug/L **[MI]**	drift algae sparse or absent, little surface microphyte mat, no visible accumulations	low numbers of individuals (153), low numbers of species (8), with low diversity (0.86) and evenness (0.30). The benthic community is structured by the habitat in the system which consists of an integration of embayment and wetland creek habitat. Benthic community is therefore consistent with high-moderate quality habitat for a wetland basin. **[H]**	assessment based on moderate impairment of benthic communities (number of species and individuals, with low diversity and evenness) with periodic hypoxia, high chlorophyll **[MI]**

Wellfleet Harbor System Embayment	Dissolved Oxygen	Chlorophyll *a*[2]	Macroalgae	Benthic Fauna[2]	Overall
Drummer Cove	oxygen levels were <4mg/L 16% (inner) and 5% (outer) of WQMP samples, >6 mg/L only 47% and 53% of outer and inner samples, with <5mg/L frequent in inner basin 37% of samples. **[H/MI]**	moderate chlorophyll *a* levels, WQMP average 10 ug/L, with blooms up to 18 ug/L **[MI]**	drift algae sparse or absent, little surface microphyte mat, no visible accumulations	low to moderate number of species (9), low to moderate number of individuals (174), low diversity (1.59) and evenness (0.51). Stress indicator species low, but community was dominated by small polychaetes (*Streblospio)*, 60%-80% of the community at most sites **[MI]**	assessment based on low impairment of benthic communities (low to moderate species and low to moderate number individuals, with low diversity and evenness) with generally moderate oxygen and chlorophyll levels. Habitat indicators consistent with a unimpaired wetland influenced basin **[MI]**
South of Lt. Island	oxygen levels, >5mg/L 96% of WQMP 212 samples, >6 mg/L (56% samples), only 2% of samples <4 mg/L. **[H]**	moderate chlorophyll *a* levels, WQMP average ~6 ug/L, with rare blooms to 22 ug/L **[H]**	drift algae sparse or absent, little surface microphyte mat, no visible accumulations	Lt. Island South had high numbers of species (18) individuals (1079) but low diversity (1.18) and evenness (0.28) indicative of some impairment**. [H/MI]**	assessment based on low-moderate impairment of benthic communities (high number of species and individuals but with low diversity and evenness) with generally high oxygen and low chlorophyll **[H/MI]**

H - Healthy habitat conditions, MI – Moderately Impaired, SI – Significantly Impaired - considerably and appreciably changed from normal conditions
SD – Severely Degraded
* These terms are more fully described in MEP report "Site-Specific Nitrogen Thresholds for Southeastern Massachusetts Embayments: Critical Indicators" December 22, 2003.
https://www.mass.gov/files/documents/2016/08/mp/nitroest.pdf

1. From "Table VIII-1. Summary of Nutrient Related Habitat Health within the Wellfleet Harbor Estuarine System (Towns of Wellfleet and Truro), based upon assessment data presented in Chapter VII. The main basin of Wellfleet Harbor and its major tributary sub-embayments have open exchange with ocean waters of Cape Cod Bay. Some basins were approximated using water quality monitoring data coupled with instrument mooring data (D.O., chlorophyll *a*). WQMP refers to water quality monitoring program." (Howes *et al*, 2017).

Duck Creek was determined to be Moderately to Significantly Impaired with tidally averaged Total Nitrogen (TN) levels of 0.93 mg/L, the highest observed in the Wellfleet Harbor Estuarine System and a concentration typically associated with significant habitat impairment in estuaries throughout southeastern Massachusetts. The MEP project found low dissolved oxygen, moderate to high levels of chlorophyll *a* and an impaired benthic community. The MEP project found a low number of species (9) and individuals (<100) and moderate diversity (2.09). In addition, the small polychaete, *Streblospio*, indicative of impaired benthic habitat, was found to dominate Duck Creek.

The MEP project found that The Cove was moderately impaired. The MEP project measured dissolved oxygen levels less than 5 mg/L 10% of the time with periodic excursions below 4 mg/L and moderate chlorophyll *a* levels (average 11 ug/L) with blooms to 20 ug/L. Additionally, the benthic community was found to be moderately impaired with moderate number of species (9), low to moderate number of individuals (164), with low diversity (1.43) and evenness (0.45). Finally, *Ampelisca abdita*, an amphipod and transitional species dominated the benthic community (>80% of the community). Amphipods are an initial recovery species frequently found in high numbers and can form mats in areas of moderate to high organic matter enrichment (Table VIII-1, MEP Tech Report).

Drummer Cove was found to be moderately impaired by the MEP project. Dissolved oxygen was often less than 5 mg/L (~37% of samples) and moderate chlorophyll *a* levels were found (average 10 ug/L) (Table 2). Furthermore, the benthic community was moderately impaired with low to moderate number of species (9), low to moderate number of individuals (174), low diversity (1.59) and evenness (0.51). While the benthic community had low numbers of stress indicator species, it was dominated (60-80%) by the small polychaete, *Steblospio,* at most sites.

The restoration target for the Wellfleet Harbor system is benthic habitat given a lack of historical evidence that the estuarine system supported significant areas of eelgrass in the main harbor. The exception is the mouth of the Herring River (aka The Gut) where eelgrass was present in 1995 and 2001. The benthic animal communities throughout most of the Wellfleet Harbor Estuary (except Duck Creek and The Cove) indicated generally healthy to slightly impaired infauna habitat to moderately-significantly impaired habitat (Duck Creek), consistent with the tidally averaged nitrogen levels and levels of chlorophyll *a* and oxygen depletion. None of the basins comprising the Wellfleet Harbor estuary showed severe degradation by nitrogen enrichment, unlike many other estuaries on Cape Cod. Reducing nitrogen concentrations within the estuary will result in the restoration of dissolved oxygen and chlorophyll *a* to levels supportive of healthy benthic infauna habitat.

Since generally only a moderate level of impairment was found in benthic habitat within the shallow semi-enclosed basins on the eastern shore, it is likely that only a modest reduction in nitrogen levels will be needed to restore infauna animal habitat in most basins, with the possible exception of Duck Creek (Howes *et. al*, 2017, ch. VIII pg. 152).

Pollutant of Concern, Sources and Controllability

In Wellfleet Harbor, as in most marine and coastal waters, the limiting nutrient is nitrogen (N). Nitrogen concentrations above those expected naturally contribute to undesirable water quality and habitat conditions (such as described above).

Wellfleet Harbor has had extensive data collected and analyzed through the MEP, with the cooperation and assistance from the Town of Wellfleet Water Quality Monitoring Program and the Cape Cod Commission. Data collection included both water quality and hydrodynamics as described in Chapters I, IV, V, and VII of the MEP Technical Report. These investigations revealed that loadings of nutrients, especially N, are much larger than they would be under natural conditions and, as a result, the water quality has deteriorated. Figure 4 illustrates the sources and percent contributions of sources of N into Wellfleet Harbor.

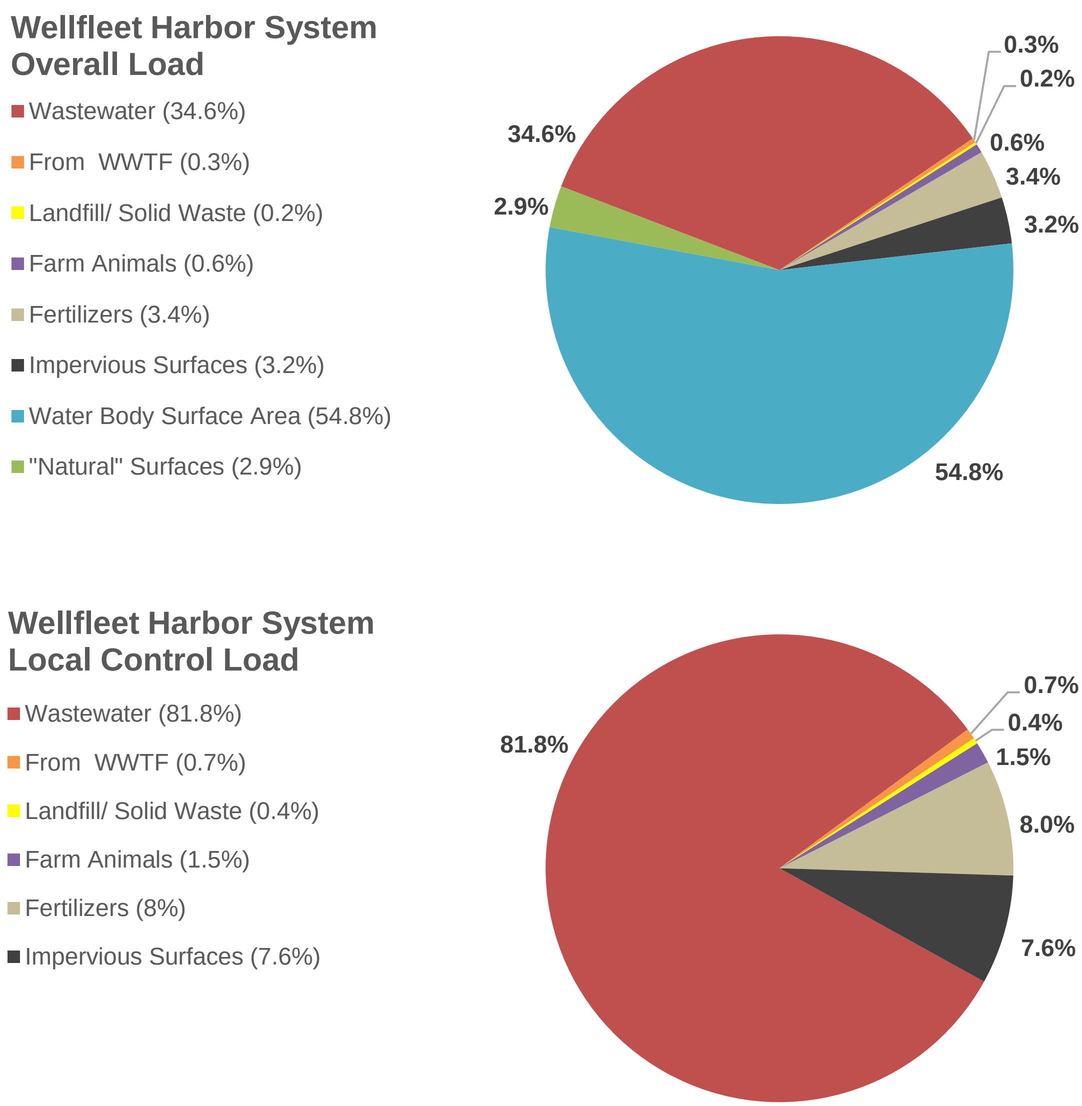


Figure 4: Percent Contribution of Watershed Nitrogen Sources to Wellfleet Harbor System (Howes *et al*, 2017)

The level of "controllability" of each source, however, varies widely as shown in Table 3 below. Cost/benefit analyses will have to be conducted for all possible N loading reduction methodologies in order to select the optimal control strategies, priorities, and schedules.

Table 3: Sources of Nitrogen and 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.

Description of the Applicable Water Quality Standards

Wellfleet Harbor is classified as a Class SA waterbody in the Massachusetts Water Quality Standards (MassDEP 2007). Massachusetts currently has narrative standards for nutrients (nitrogen and phosphorus) for waters of the Commonwealth 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. These data were used by SMAST to assess the loading capacity of each sub-embayment. Physical (Chapter V), chemical, and biological (Chapters IV, VII, and VIII**)** data were collected and evaluated. The primary water quality objective was represented by conditions that:

1) Prevent algal blooms;
2) Restore and protect benthic communities; and
3) Maintain dissolved oxygen concentrations that are protective of the estuarine communities.
4) Protect and restore eelgrass community and habitat

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 of this study are summarized below.

The core analytical method of the Massachusetts Estuaries Project 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 previously been applied to watershed N management in numerous embayments throughout Southeastern Massachusetts. In these applications it became clear that the model can be calibrated and validated and has use as a management tool for evaluating watershed N management options.
The Linked Model, when properly calibrated and validated for a given embayment, becomes a N management planning tool as described in the model overview below. The model can assess solutions for the protection or restoration of nutrient-related water quality and allows testing of management scenarios to support cost/benefit evaluations. In addition, once a model is fully functional it can be refined for changes in land-use or embayment characteristics at minimal cost. Also, 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-3 of the MEP Technical Report). This methodology integrates a variety of field data and models, specifically:

- Monitoring - multi-year embayment nutrient sampling;

- Hydrodynamics;
  - Embayment bathymetry (depth contours throughout the embayment)
  - Site-specific tidal record (timing and height of tides)
  - Water velocity records (in complex systems only)
  - Hydrodynamic model

- Watershed N Loading;
  - Watershed delineation
  - Stream flow (Q) and N load
  - Land-use analysis (GIS)
  - Watershed N model

- Embayment TMDL – Synthesis;
  - Linked Watershed-Embayment N Model

- ➢ Salinity surveys (for linked model validation)
- ➢ Rate of N recycling within embayment
- ➢ Dissolved oxygen record
- ➢ Chlorophyll *a* record
- ➢ Eelgrass and Infauna surveys

Application of the Linked Watershed-Embayment Model

The approach developed by the MEP for applying the linked model to specific embayments for the purpose of developing target threshold 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 three years of sub-embayment-specific data to select target threshold N concentrations for each sub-embayment. This is done by refining the draft target threshold N concentrations that were developed as the initial step of the MEP process. The target threshold N concentrations that were selected generally occur in higher quality waters near the mouth of the embayment system;

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

Previous sampling and data analyses and the modeling activities described above resulted in four major outputs that were critical to the development of the TMDL.

Two outputs are related to N **concentration**:

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

Two outputs are related to N **loadings:**

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

In summary, meeting the water quality standards (for dissolved oxygen, nutrients) by reducing the N concentration (and thus the N load) at the sentinel station, the water quality goals will be met throughout the entire system.

A brief overview of each of the outputs follows.

Nitrogen concentrations in the embayment

1) Observed "present" conditions:

Table 4 presents the average concentrations of N measured in this system from data collected at twelve stations during the period 2003 through 2011 (additional details in Appendix B). Average yearly nitrogen concentrations at these stations ranged from 0.485 – 0.908 mg/L with the lowest average concentration found in the lower Wellfleet Harbor (Station WH-1) and the highest average within the Duck Creek station (WH-12). See Figure 5 for station locations. The overall means and standard deviations of the averages are presented in Appendix B, Table B-1 (reprinted from Table VI-1 of the MEP Technical Report, Howes *et al*, 2017). The sentinel station is WH-5, located in Upper Wellfleet Harbor.

Table 4: Observed Present Nitrogen Concentrations and Sentinel Station Threshold Nitrogen Target Concentration for Wellfleet Harbor.

Sub-Embayment	Station[1]	**Mean[2]** (mg/L N)	Standard Deviation	Target Threshold Nitrogen Concentration (mg/L)
Lower Wellfleet Harbor	WH-1	0.485	0.170	
Lower Wellfleet Harbor	WH-2	0.511	0.160	
Wellfleet Harbor by Audubon	WH-3	0.542	0.158	
Mid Wellfleet Harbor	WH-4	0.539	0.147	
Upper Wellfleet Harbor	WH-5	0.547	0.152	**0.53**
Lower Blackfish Creek	WH-6	0.618	0.170	
Upper Blackfish Creek	WH-7	0.638	0.126	
The Gut	WH-8	0.722	0.168	
Herring River the Gut	WH-9	0.741	0.214	
Outer Cove	WH-10	0.762	0.213	
The Cove	WH-11	0.849	0.231	
Duck Creek	WH-12	0.908	0.234	

[1] Station locations including, Sentinel Station (WH-5), shown in Figure 5.
[2] Mean values are calculated as the average of all measurements. Data collected in the summers of 2003 through 2011. Also refer to Appendix B.

2) Modeled site-specific target threshold N concentrations:

A major component of TMDL development is the determination of the maximum concentrations of N (based on field data) that can occur without causing unacceptable impacts to the aquatic environment. This is called the *target threshold nitrogen concentration*. Prior to conducting the analytical and modeling activities to determine this target threshold N concentration as described below, 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.

The approach for determining nitrogen loading rates, which will maintain acceptable habitat quality throughout an embayment system, is to first identify a sentinel location within the embayment and second to determine the nitrogen concentration within the water column which will restore that location to the desired habitat quality. The sentinel location is selected such that the restoration of that one site will necessarily bring the other regions of the system to acceptable habitat quality levels.

Once the sentinel site and its target threshold nitrogen concentration are determined, the MEP study modeled nitrogen loads until the targeted nitrogen concentration was achieved. Determination of the critical nitrogen threshold for maintaining high quality habitat within Wellfleet Harbor is based primarily on the nutrient and oxygen levels and benthic community indicators. The N threshold for Wellfleet Harbor is based upon the goal of restoring benthic habitat for infauna animals in the Wellfleet Harbor System.

As listed in Table 4 above, the site-specific target threshold N concentration is 0.53 mg/L. The findings of the analytical and modeling investigations to determine this target threshold nitrogen concentration for the estuarine system are discussed below.

Figure 5: Wellfleet Harbor Long Term Monitoring Stations. Sentinel Station is Station WH-5 for benthic habitat recovery.

As previously described, the Wellfleet Harbor Estuary is a complex estuary composed of three types of basins: shallow open water basins with no eelgrass or surrounding wetland, shallow basins with significant associated wetland, and a large open lagoon with high tidal velocities near the inlet and areas of shifting sands (lower main basin). Each of these three basins has different natural sensitivities to nitrogen enrichment and organic matter loading and each has its own benthic community indicative of an unimpaired or impaired habitat. The benthic animal communities throughout most of the Wellfleet Harbor Estuary (except Duck Creek, Drummer Cove and The Cove) indicated generally healthy to slightly impaired infauna habitat. None of the basins comprising the Wellfleet Harbor Estuary showed severe degradation by nitrogen enrichment, unlike many other estuaries on Cape Cod. (Howes *et. al*, chVII-4, 2017). Since there is no eelgrass habitat within the main Wellfleet Harbor Estuary, restoring impaired benthic animal habitat is the primary management objective for this system. (Eelgrass was observed historically in the mouth of the Herring River and is discussed below.) Generally, only a moderate level of impairment was found in benthic habitat within the shallow semi-enclosed basins on the eastern shore, therefore it is likely that only a modest reduction in nitrogen levels will be needed to restore infauna animal habitat in most basins, with the possible exception of Duck Creek.

To restore infauna habitat in Wellfleet Harbor estuarine system a threshold for tidally averaged TN at long-term monitoring station WH-5 in the upper main basin was selected to restore benthic animal habitat. In this system, meeting the 0.53 mg/L TN (tidally averaged) at station WH-5 for benthic habitat restoration should ensure restoration of benthic animal habitat throughout the estuary.

The infauna survey indicated that certain basins comprising the overall Wellfleet Harbor Estuary are presently supporting impaired benthic infauna habitat (Howes *et. al*, 2017 Table VII-4). However, none of the basins had benthic communities with significant numbers of stress indicator species (e.g., *tubificids, capitellids*), which are typically found in highly nutrient and organic matter enriched estuarine basins. These species, where they did occur, generally comprised <5% of the community and were always less than 12% of the individuals present (Howes *et al*, 2017 pg. 143). Other species consistent with moderately impaired benthic habitat were found in Duck Creek, The Cove and Drummers Cove (See Table 2). Generally, the communities throughout the system were comprised of crustaceans, mollusks, and polychaetes, with some deep burrowers, indicative of a system supporting moderate to high quality benthic habitat.

Total nitrogen levels (TN) within Wellfleet Harbor revealed summer-time, tidally-averaged, means by station that ranged between 0.485 to 0.908 mg/L (means of all data per station collected summers between 2003 and 2011, as reported in Chapter VI of the MEP Technical Report and reprinted in Appendix B).

Within the Wellfleet Harbor Embayment System is a critical habitat structuring the productivity and resource quality of the entire system, and given that it is presently showing moderate impairment, restoration of this resource is the primary target for overall restoration of this system.

It should also be noted that in numerous estuaries evaluated by the MEP, it has been previously determined that 0.500 mg/L TN is the upper limit to sustain unimpaired benthic animal habitat (e.g., Eel Pond {Waquoit Bay}, Parkers River, upper Bass River, upper Great Pond, Rands Harbor and Fiddlers Cove). Present TN levels within the upper reaches of the open water subbasins of Wellfleet

Harbor Estuary are >0.55 mg/L TN, consistent with moderately impaired benthic animal habitat. Based upon comparisons to other systems and given the TN levels in the non-wetland influenced basins, the periodic oxygen depletions and the phytoplankton blooms, it appears that a water column nitrogen threshold for the main basin of 0.53 mg/L TN with 0.50 for the eastern sub-basins is required for restoration in this system. This slightly higher threshold is due in part to the well mixed, oxygenated nature of the main basin (resulting from its shallow depth and large fetch for wind driven mixing). In addition, this lagoon does not support high rates of organic deposition, evidenced by the observed generally sandy sediments with oxidized surfaces. The semi-enclosed sub-basins on the eastern shore are less well mixed and allow more organic deposition, such that a level of 0.50 mg TN L-1 would be more conducive to high quality benthic habitat. (Howes *et al*, 2017, ch. VII p. 155).

The restoration target for the main Wellfleet Harbor is benthic habitat due to the lack of historical eelgrass observed there. However, small patches of eelgrass were recorded at the mouth of the Herring River in 1995 and 2001, during eelgrass surveys completed by MassDEP (MassGIS, 2018). Eelgrass declined by more than 50% between 1995 and 2001 and no eelgrass was mapped in the area in any of the following surveys completed in 2006/7, 2010, and 2015. The restoration target for the Herring River (MA96-33) is for eelgrass habitat to be address through an Alternative Restoration Plan discussed below.

Nitrogen loadings to the embayment

1) Present loading rates:

In the Wellfleet Harbor 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 82% of the controllable N load to the overall system. Other controllable sources include fertilizers (8%), and runoff from impervious surfaces (8%). Septic system loading is 52.67 kg N/day within the entire Wellfleet Harbor estuarine system. The total N loading from all sources is 79.74 kg/day. A further breakdown of N loading by source is presented in Table 5. The data on which Table 5 is based can be found in Table ES-1 of the MEP Technical Report.

2) Nitrogen loads necessary for meeting the site-specific target threshold N concentrations:

The nitrogen threshold 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 benthic infauna habitats in the Wellfleet Harbor 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 sentinel station chosen for Wellfleet Harbor (WH-5). 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.

Table 5: Present Attenuated Nitrogen Loading to the Wellfleet Harbor Embayment System (from Howes *et. al*, 2017)

System Component	Present Land Use Load N[1] (kg/day)	Present Attenuated Septic System Load N (kg/day)	Present Total Attenuated Watershed Load N[2] (kg/day)	Direct Atmospheric Deposition N[3] (kg/day)	Present Net Benthic Flux N (kg/day)	Total N Load from All Sources[4] (kg/day)
Herring River/The Gut	15.97	11.75	27.72	2.81	18.70	51.18
Duck Creek	1.16	4.24	5.40	--	17.88	25.22
The Cove	1.85	7.97	9.82	2.22	133.46	160.75
Drummer/Blackfish	1.56	5.80	7.36	1.66	6.47	16.33
Hatches Creek	2.16	7.30	9.46	0.15	-7.84	1.03
Wellfleet Harbor	3.85	13.68	17.53	64.72	44.61	129.76
Loagy Bay	0.52	1.93	2.45	0.99	8.65	13.19
Wellfleet Harbor (total system)	27.07	52.67	79.74	72.55	245.17	397.46

1 -Present Land Use Load is composed of non-septic loads, (e.g., fertilizer, landfill, wastewater treatment facilities, agriculture, runoff from impervious and natural surfaces) and atmospheric deposition.
2 -Present Total Attenuated Watershed Load is Present Land Use Load plus septic system loadings.
3 -atmospheric deposition to embayment surface only.
4 -composed of Present Total Attenuated Watershed Load, Direct Atmospheric Deposition and Present Net Benthic Flux loadings.

Table 6 includes the present and target threshold watershed N loadings to Wellfleet Harbor and the percentage reduction necessary to meet the target threshold N concentration at the sentinel station (from Table ES-2 of the MEP Technical Report, Howes *et. al*, 2017).

It should be emphasized that this is only one scenario that will meet the target N concentration enough to restore habitat throughout the system which is the goal of the TMDL. There can be variations depending on the chosen sub-watershed and which controllable source is selected for reduction. Alternate scenarios will result in different amounts of nitrogen being reduced in different sub-watersheds. For example, taking out additional nitrogen upstream will impact how much nitrogen must be taken out downstream. The town of Wellfleet should take any reasonable effort to reduce the controllable nitrogen sources.

As previously indicated, the present N loadings to Wellfleet Harbor 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.

Table 6: Present 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 Loadings

System Component	Present Attenuated Watershed Load[1] (kg/day)	Target Threshold Watershed Load[2] (kg/day)	Percent watershed reductions needed to achieve target threshold loads
Herring River/The Gut	27.72	27.13	-2.1%
Duck Creek	5.40	1.80	-66.7%
The Cove	9.82	3.04	-69.0%
Drummer/Blackfish	7.36	3.59	-51.2%
Hatches Creek	9.46	9.46	+0.0%
Wellfleet Harbor	17.53	8.64	-50.7%
Loagy Bay	2.45	1.19	-51.2%
Wellfleet Harbor (total system)	79.74	54.85	-31.4%

[1] Composed of wastewater from septic systems, fertilizer, landfill, wastewater treatment facilities, agriculture, runoff from impervious surfaces, atmospheric deposition to freshwater waterbodies and natural surfaces. This load does not include direct atmospheric deposition onto estuarine surfaces or benthic regeneration.
[2] Target Threshold Watershed Load is the load from the watershed needed to meet the embayment target threshold N concentration of 0.53 mg/L identified in Table 4 above.

Total Maximum Daily Loads

As described in EPA guidance, a total maximum daily load (TMDL) identifies the loading capacity of a water body for a 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, benthic habitat, 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 TMDL for the Wellfleet Harbor system is 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.

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 benthic infauna (the primary indicator), as well as dissolved oxygen and chlorophyll.

The TMDL can be defined by the equation:

TMDL = WLAs + LAs + MOS

Where:

TMDL = loading capacity of receiving water

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. Background loading is accounted for in this TMDL but not defined as a separate component. Refer to Table ES-1 of the MEP Technical Report for estimated loading due to natural conditions.

Waste Load Allocations

Waste load allocations (WLA) identify the portion of the loading capacity allocated to existing and future point sources of wastewater. In the Wellfleet Harbor estuarine system there are no NPDES[1]

[1] National Pollutant Discharge Elimination System

regulated point source discharges in the watershed. EPA interprets 40 CFR 130.2(h) to require that allocations for NPDES regulated discharges of storm water also be included in the waste load component of the TMDL. It should be noted that although a portion of the town of Wellfleet is designated as an urbanized area by EPA, the town requested and received a waiver from the current requirements of Massachusetts Stormwater MS4[2] permit (EPA 2016). This waiver does not constitute a complete exemption from the stormwater program. EPA will periodically review the information in the waiver request and determine if conditions have substantially changed.

In MS4 communities where an estimate of the nitrogen loadings from regulated stormwater sources was needed, MassDEP considered that most stormwater runoff on Cape Cod and the Islands is not discharged directly into surface waters, but, rather, percolates into the ground. The geology on Cape Cod and the Islands 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 and the Islands was never undertaken prior to the MEP study used in the development of this TMDL. Nevertheless, most catch basins on Cape Cod and the Islands are known to MassDEP to have been designed as leaching catch basins considering the permeable sediments. Therefore MassDEP, recognized that most stormwater that enters a catch basin will percolate into the local groundwater table rather than directly discharge to a surface waterbody.

The majority of the watershed nitrogen loading comes from septic systems and to a lesser extent fertilizer, the landfill and storm-water runoff that infiltrates into the groundwater, the allocation of nitrogen for any storm-water pipes that discharge directly to any of the embayments is expected to be insignificant as compared to the overall groundwater load. 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 may be 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 they in fact did so. MassDEP selected this approach because it considered it unlikely that any stormwater collected farther than 200 feet 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.

MassDEP has calculated the potential waste load allocation for this 200-foot buffer zone previously in a number of total nitrogen TMDLs for embayments on Cape Cod. The calculated waste load allocation due to runoff from impervious surfaces within 200 feet of the estuary system is 0.59 kg/day, 0.71 % of the total unattenuated watershed load. (Refer to Appendix C for details.) This conservative 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 Wellfleet Harbor system, the controllable nonpoint source loadings are

[2] Small Municipal Separate Storm Sewer System

primarily from on-site subsurface wastewater disposal systems. 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 atmospheric deposition. Nitrogen load from the wastewater treatment facility, farm animals, and the landfill contribute ≤1% each.

Figure 4 (above) and Figure 6 (below) illustrate that septic systems are the most significant portion of watershed sources of controllable attenuated nitrogen (52.7 N/day), with fertilizers from lawns and golf courses a distant second (5.23 kg N/day). Another watershed source of controllable nitrogen is stormwater runoff, which contributes 4.96 kg N/day (from Table IV-3 in the MEP Technical Report). In addition, there are nonpoint sources of N from sediments, natural background and atmospheric deposition that are not feasibly controllable but are included in the Load Allocation of the TMDL.

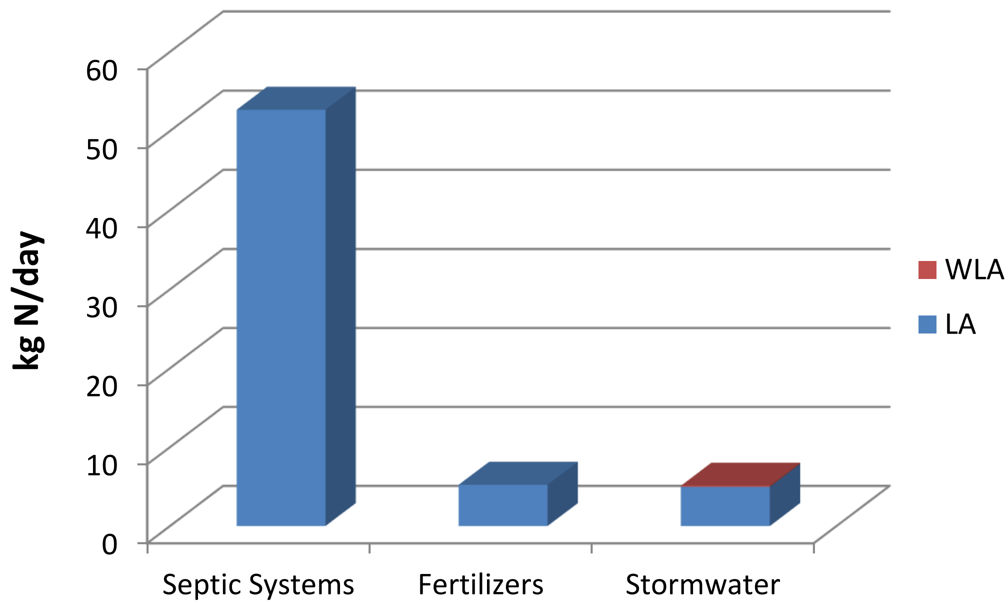


Figure 6: Controllable Watershed Sources of Nitrogen Loading to the Wellfleet Harbor Estuarine System

Wellfleet received a waiver in 2016 from the requirements of the EPA Phase II Stormwater Program. 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, thus defining the stormwater in pervious areas to be a component of the non-point source load allocation. As discussed above, even though there are measurable 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.

Sediment loading rates incorporated into the TMDL are different than the existing sediment flux rates 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 flux of nitrogen from bottom sediments is a critical (but often overlooked) component of nitrogen loading to the shallow estuarine systems, therefore determination of the site-specific magnitude of this component was also performed (see Section VI of the MEP Report).

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 Wellfleet Harbor system is reduced (towards zero) from existing conditions based on the N load reduction from controllable sources. There was one exception to this rule. Since there was a negative benthic flux (nutrient uptake) recorded in Hatches Creek under present conditions, a more conservative approach was used for these segments in the TMDL by assuming zero benthic flux for these segments in the future. This conservative approach was used and is considered part of the margin of safety in the TMDL. Since benthic loading varies throughout the year and the values shown represent "worst case" summertime conditions, loading rates are presented in kilograms per day.

The loadings from atmospheric sources incorporated into the TMDL are the same rates presently occurring because, as discussed above, significant control of atmospheric loadings at the local level 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)(20C, 40C.G.R. para 130.7C(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 (USEPA, 1991) 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 Wellfleet Harbor estuarine system TMDL 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 (Executive Office of Energy and Environmental Affairs and Adaptation Advisory Committee, 2011 Massachusetts Climate Change Adaptation Report). 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. Nitrogen from the upper watershed regions which travel through ponds or wetlands almost always enters the embayment via stream flow and is directly measured (over 12-16 months) to determine attenuation. In these cases, the land-use model has shown a slightly higher predicted N load than the measured discharges in the streams/rivers that have been assessed to date. Therefore, the watershed model as applied to the surface water watershed areas again presents a conservative estimate of N loads because the actual measured N in streams was lower than the modeled concentrations.

The hydrodynamic and water quality models have been assessed directly. In the many instances where the hydrodynamic model predictions of volumetric exchange (flushing) have also been directly measured by field measurements of instantaneous discharge, the agreement between modeled and observed values has been $\geq$94% (Howes *et. al* 2017, pg. 101). 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 0.04 mg/l and an R^2 correlation of 0.93 at key stations, which demonstrates a good fit between modeled and measured data for this system (Howes *et. al* 2017, pg. 115). Since the water quality model incorporates 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 so less of a margin of safety is required.

In the Wellfleet Harbor Estuarine System, there are eight freshwater ponds with delineated watersheds: Great, Ryder, and Snow Ponds in Truro and Duck, Dyer, Great, Herring, and Long Ponds in Wellfleet. Of these eight ponds, two have available bathymetry (Duck and Long) according to the Cape Cod Pond and Lake Atlas (PALS) (Eichner, *et al.*, 2003). PALS water quality sampling shows each of these ponds have been sampled. For the two ponds with both bathymetry and water quality sampling data, neither had enough sampling outside of the PALS Snapshots to assign a pond-specific nitrogen attenuation rate. This data review supports the use of the standard MEP pond 50% nitrogen attenuation rate for all ponds in within the Wellfleet Harbor study area.

Similarly, the water column N validation dataset was also conservative. The model is calibrated to measured water column N and validated to salinity. 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 of the amount of N released from the sediments are most likely underestimates, i.e. conservative. The reduction is based solely on a reduced deposition of particulate organic nitrogen (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 negative benthic flux in Hatches Creek, -8.58 kg/day N,) does not exist under future loading conditions and as such was designated as “0” 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 re-mineralized 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 station and target threshold N concentration. The sites were chosen that had stable benthic animal (infauna) communities, and not those just starting to show impairment, which would have slightly higher N concentration. Meeting the target threshold N concentration at the sentinel station will result in restoration of benthic habitat throughout the rest of the system.

3. Conservative approach

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

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 regulated stormwater 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 described above, a programmatic margin of safety also derives from continued monitoring of this embayment 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 management necessary to control the N load do not lend themselves to intra-annual manipulation since a considerable portion 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.

Alternative TMDL for the mouth of the Herring River (The Gut)

In 2013, the EPA announced a new framework (Vision) for prioritizing and implementing TMDLs and pollution control strategies (USEPA, 2013). The guidance for this Vision allows states to adopt strategies tailored to their water quality program goals and priorities. The Vision acknowledges that alternative restoration approaches may be more immediately beneficial or practical in achieving water quality standards than a traditional TMDL. Additional load reductions from the watershed, beyond the proposed load reductions for benthic habitat restoration, are needed to re-establish eelgrass in the Herring River are likely needed. Therefore, MassDEP will be pursuing an alternative restoration approach for the mouth of the Herring River to address nonattainment of nutrient related water quality standards.

MassDEP is working with EPA on an Alternative Restoration Plan through the Herring River Restoration Project. The project includes removal of the Chequessett Dike Dam and replacement with a bridge and a control structure to allow managed increases in tidal flow. The new bridge will have a 165-foot wide opening compared to the existing three 6-foot wide culverts (Fuss and O'Neil, 2019). This project is proposed as a long-term, phased increase in tidal flow to avoid unexpected or irreversible changes to the river or Wellfleet Harbor (Friends of Herring River, 2020). Replacement of the Chequessett Dike Dam is expected to achieve Massachusetts Surface Water Quality Standards in the 0.4 mi^2 area of the mouth of the Herring River and to restore water quality and habitat for six river miles above the dam.

The restructuring of the Chequessett Neck Dike will allow tidal flushing of the marshlands with oxygen rich oceanic water for fish, crustaceans and invertebrates like oysters and clams. Tidal flooding also brings in sediment which helps the marsh against rising sea level and promotes growth of marsh grasses. High tidal range eases the passage and improves habitats for migratory fish, birds and shellfish. The removal of the dike will improve water quality, re-establish salt marsh and estuarine vegetative habitat and reduce invasive species (Friends of Herring River, 2020). With improved tidal circulation and flushing of TN in the mouth of the Herring River, restoration of eelgrass habitat is expected.

Significant degradation of the habitat within Herring River and its contributing watershed has occurred over many decades due to the construction of the Chequessett Dike Dam in 1909. Former salt marshes have become disturbed freshwater wetlands or dry deciduous woodlands. Changes to water quality include high acidity and low dissolved oxygen, resulting in fish kills. High fecal coliform bacteria counts have resulted in closure of shellfish beds. Poor tidal flushing and water quality degradation have resulted in a loss of predatory fish and an increase in nuisance mosquitoes which was one of the original reasons for its construction (Herring River Technical Committee, 2007).

Although restoration of the Herring River (MA96-33) is expected to occur over time as the Herring River Restoration Project is implemented in phases, the waterbody will remain on the 303(d) list (Category 5, Waters Requiring a TMDL) until Massachusetts Surface Water Quality Standards are met, eelgrass habitat is restored, or a traditional TMDL is approved.

TMDL Values for the Wellfleet Harbor System

As outlined above, the total maximum daily loadings of N that would provide for the restoration and protection of the embayment were calculated by considering all sources of N grouped by natural background, point sources and non-point sources.

In Table 7, N loadings from the atmosphere and from nutrient rich sediments are listed separately from the target watershed threshold loads. The watershed load is composed of atmospheric deposition to freshwater and natural surfaces along with locally controllable N from on-site subsurface wastewater disposal systems, storm water runoff, and fertilizer sources. In the case of the Wellfleet Harbor system, the TMDL was calculated by projecting reductions in locally controllable watershed sources of N. 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. The goal of the TMDL for Wellfleet Harbor is to achieve the identified target threshold N concentration at the identified sentinel station.

Table 7: The Nitrogen Total Maximum Daily Load for the Wellfleet Harbor System

System Component	Target Threshold Watershed Load[1] (kg N/day)	Atmospheric Deposition (kg N/day)	Load from Sediments[2] (kg N/day)	TMDL[3] (kg N/day)
Herring River/The Gut	27.13	2.81	18.70	48.64
Duck Creek	1.80	-	17.88	19.68
The Cove	3.04	2.22	133.46	138.72
Drummer/Blackfish	3.59	1.66	6.47	11.72
Hatches Creek	9.46	0.15	0	9.61
Wellfleet Harbor	8.64	64.72	44.61	117.97
Loagy Bay	1.19	0.99	8.65	10.83
Wellfleet Harbor (total system)	54.85	72.55	221.93	357.17

1 Target threshold watershed load is the load from the watershed needed to meet the embayment target threshold nitrogen concentration identified in Table 4.
2 Projected future flux (present rates reduced approximately proportional to watershed load reductions). (Negative fluxes set to zero.)
3 Sum of target threshold watershed load, atmospheric deposition load and sediment load.

Implementation Plans

The critical element of this TMDL process is achieving the sentinel station specific target threshold N concentration presented in Table 4. This is necessary for the restoration and protection of water quality and benthic invertebrate habitat within the Wellfleet Harbor System. In order to achieve these target threshold N concentrations, N loading rates must be reduced throughout the Wellfleet Harbor embayment system. Table 7 above lists the target threshold watershed N load for this system.

Herring River Restoration Project:
Following years of hydrologic and ecologic research, the Herring River Restoration Project has completed state and federal permitting. The Herring River Restoration Committee and the National Park Service prepared the Environmental Impact Statement/Environmental Impact Report and received the Record of Decision approval September 2016 through National Environmental Policy Act (NEPA) reviews and the Massachusetts Environmental Policy Act (MEPA) certificate was issued in July 2016. Phase I was approved by the Cape Cod Commission on June 15, 2020 (Cape Cod Times, 2020). Phase I includes removal of the Chequessett Dike Dam and replacement with a bridge and a control structure to allow managed increases in tidal flow. The Herring River Restoration Project also includes raising low-lying roads so that there is safe passage under all tidal conditions. Upper Pole Road will be raised and a larger culvert installed with an attached tide gate to manage water levels locally, separate from the main system. Similarly, a dike at Mill Creek will be constructed to manage water levels locally, separate from the main system.

This project is proposed as a long-term, phased increase in tidal flow to avoid unexpected or irreversible changes to the river or Wellfleet Harbor (Friends of Herring River, 2020). In August 2020, the Massachusetts Division of Ecological Restoration awarded the Herring River Restoration Project $500,000 which will allow project proponents to leverage an additional $1 million of federal funding (MassDER, 2020).

Septic Systems:
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. 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 the Clean Water Act Section 208.

Table 8 (from Table VIII-2 of the MEP Technical Report) summarizes the present loadings from septic systems and the reduced loads that would be necessary to achieve the target threshold N concentration in the Wellfleet Harbor system under the scenario modeled here. A 47.4% reduction in present septic loading achieved the target threshold N concentration of 0.53 mg/L at the sentinel station (Station WH-5), time averaged over the summer period. This septic load change will result in a 47.4% decrease in the total watershed load to the Wellfleet Harbor Estuary.

Table 8: Summary of the Present Septic System Loads and the Loading Reductions that Would be Necessary to Achieve the TMDL by Reducing Septic System Loads Alone.

System Component	Present Septic N Load (kg N/day)	Threshold Septic load (kg N/day)	Threshold Septic Load % Change
Herring River/The Gut	11.75	11.16	-5.0%
Duck Creek	4.24	0.64	-85.0%
The Cove	7.97	1.19	-85.0%
Drummer/Blackfish	5.80	2.03	-65.0%
Hatches Creek	7.30	7.30	+0.0%
Wellfleet Harbor	13.68	4.79	-65.0%
Loagy Bay	1.93	0.67	-65.1%
Wellfleet Harbor (total system)	52.67	27.68	-47.4%

The above modeling results provide one scenario of achieving the threshold level for the sentinel site within the estuarine system. This example does not represent the only method for achieving this goal. The towns of Wellfleet, Truro and Eastham are encouraged to evaluate other load reduction scenarios and take any reasonable steps to reduce the controllable N sources.

The Town of Wellfleet requested an alternative buildout scenario based on an interim 2030 development forecast. This scenario did not look at land classification, but rather evaluated housing and populations trends. This analysis completed by the Town CWMP committee resulted in 131 new dwelling units in Wellfleet at 2030, as compared to MEP estimate of 1,517 new dwelling units based on development of all available properties in accordance with current zoning. Based on the alternative buildout assessment, buildout additions within the Wellfleet Harbor watersheds will increase the unattenuated watershed nitrogen loading rate by 3% (compared to a 32% increase in nitrogen load under full build-out). The comparison of present and alternative buildout scenario total watershed loads is presented in Table IX-1 on MEP report.

Stormwater:
EPA granted the town of Wellfleet a waiver from the Massachusetts Stormwater MS4 permit requirements (because it is located in a jurisdiction with a population under 1,000 within the urbanized area as defined by the 2010 Census) and at this time is not required to obtain permit coverage for stormwater discharges from their small MS4 (EPA 2016). The NPDES permitting authority is required to periodically review any waivers granted to MS4 operators to determine whether any information required for granting the waiver has changed and EPA may require the

town of Wellfleet to seek permit coverage in the future. 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 Massachusetts Surface Water Quality Standards.

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, and
6. Pollution prevention/good housekeeping.

Communities applying for Phase II permit coverage, 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.

Climate Change:
MassDEP recognizes that long-term (25+ years) climate change impacts to southeastern Massachusetts, including the area of this TMDL, are occurring based on known science. Massachusetts Executive Office of Energy and Environmental Affairs and Adaptation Advisory Committee 2011 Climate Change Adaptation Report 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 (Executive Office of Energy and Environmental Affairs and Adaptation Advisory Committee 2011, 2011 Massachusetts Climate Change Adaptation Report). 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://water.epa.gov/scitech/climatechange/upload/epa_2012_climate_water_strategy_full_report_final.pdf) 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 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 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 estuarine system the TMDL can be reopened, if warranted.

Implementation Guidance

The watershed communities of Wellfleet, Truro and Eastham 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 on-site subsurface wastewater disposal system loadings as well as reductions in stormwater runoff and/or fertilizer use within the watershed through the establishment of local by-laws and/or the implementation of stormwater Best Management Practices (BMPs).

MassDEP's MEP Implementation Guidance report (https://www.mass.gov/lists/water-resources-policies-guidance#coastal-resources-&-estuaries-) provides N loading reduction strategies that are available to Wellfleet that could be incorporated into the implementation plans. The following topics related to N reduction are discussed in the Guidance:

- Wastewater Treatment;
    - On-Site Treatment and Disposal Systems
    - Cluster Systems with Enhanced Treatment

  - Community Treatment Plants
  - Municipal Treatment Plants and Sewers
- Tidal Flushing;
  - Channel Dredging
  - Inlet alteration
  - Culvert Design and Improvements
- Stormwater Control and Treatment*;
  - Source Control and Pollution Prevention
  - Stormwater Treatment
- Attenuation via Wetlands and Ponds;
- Water Conservation and Water Reuse;
- Management Districts;
- Land Use Planning and Controls;
  - Smart Growth
  - Open Space Acquisition
  - Zoning and Related Tools
- Nutrient Trading.

* The Town of Wellfleet is not one of the 237 communities in Massachusetts covered by the Phase II stormwater program requirements.

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 may be needed in the future. The two forms of monitoring include: 1) tracking implementation progress as approved in the town CWMP plan (as appropriate); and 2) monitoring ambient water quality conditions, including but not limited to, the sentinel station identified in the MEP Technical Report.

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

Relative to water quality, MassDEP believes that an ambient monitoring program, much reduced from the data collection activities needed to properly assess conditions and to populate the model, will be important to determine actual compliance with water quality standards. Although the TMDL load values are not fixed, the target threshold N concentrations at the sentinel stations are. Through discussions amongst the MEP it is generally agreed that existing monitoring programs which were designed to thoroughly assess conditions and populate water quality models can be substantially reduced for compliance monitoring purposes. Although more specific details need to be developed on a case by case basis, MassDEP's current thinking is that about half the current effort (using the same data collection procedures) would be sufficient to monitor compliance over time and to observe trends in water quality changes. In addition, the benthic habitat and communities would require periodic monitoring on a frequency of about every 3-5 years.

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 through its many permitting programs, 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. Wellfleet has demonstrated this commitment through the comprehensive wastewater planning that they initiated well before the generation of the TMDL, as well as, proceeding Herring River tidal and habitat restoration. The town expects to use the information in this TMDL to generate support from their citizens to take the necessary steps to remedy existing problems related to N loading from on-site subsurface wastewater disposal systems, stormwater, and runoff (including fertilizers) and to prevent any future degradation of these valuable resources.

Moreover, reasonable assurances that the TMDL will be implemented include enforcement of regulations, availability of financial incentives and local, state and federal programs for pollution control. 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

To be completed.

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Appendix A: Overview of Applicable Surface Water Quality Standards

Water quality standards that govern surface water conditions that may result from cultural eutrophication are dissolved oxygen, nutrients, bottom pollutants or alterations, aesthetics, excess plant biomass, and nuisance vegetation. The Massachusetts Surface Water Quality Standards (SWQS, 314 CMR 4.00) contain numeric criteria for dissolved oxygen, site-specific numeric and narrative standards for nutrients, and solely narrative standards for the other variables. This brief summary does not supersede or replace 314 CMR 4.00. A complete version of the SWQS is available online (MassDEP 2021).

Applicable Narrative Standards

The following narrative standards are excerpted from the SWQS:

> 314 CMR 4.05(5)(a): *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): *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): *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 including, but not limited to, those established in 314 CMR 4.06(6)(c): *Table 28: Site-specific Criteria*. 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

The following class descriptions and numeric standards are excerpted from the SWQS:

> 314 CMR 4.05(4)(a): *Class SA*. Those Coastal and Marine Waters so designated pursuant to 314 CMR 4.06; including, without limitation, 314 CMR 4.06(2) and (5), and certain qualified waters designated in 314 CMR 4.06(6)(b). 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 for shellfishing in 314 CMR 4.06(6)(b), these waters shall be suitable for shellfish harvesting without depuration (Approved and Conditionally Approved Shellfish Areas). These waters shall have excellent aesthetic value.

314 CMR 4.05(4)(a)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.

314 CMR 4.05(4)(b): *Class SB*. Those Coastal and Marine Waters so designated pursuant to 314 CMR 4.06; including, without limitation, 314 CMR 4.06(2) and certain surface waters designated in 314 CMR 4.06(6)(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. In certain waters, habitat for fish, other aquatic life and wildlife may include, but is not limited to, seagrass. Where designated for shellfishing in 314 CMR 4.06(6)(b), these waters shall be suitable for shellfish harvesting with depuration (Restricted and Conditionally Restricted Shellfish Areas). These waters shall have consistently good aesthetic value.

314 CMR 4.05(4)(b)1.: *Dissolved Oxygen*. Shall not be less than 5.0 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.

Surface Waters Not Specifically Designated in 314 CMR 4.06

Note many waterbodies do not have a specific water quality designation in 314 CMR 4.06: *Classification, Figures, and Tables***.** Those that do not have a specific designation are classified by category. Coastal and Marine Classes of water are designated as Class SA and presumed High Quality Waters as described in 314 CMR 4.06 (5).

314 CMR 4.06(5): *Other Waters*. Unless otherwise designated in 314 CMR 4.06: *Classification, Figures, and Tables*, 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: *Antidegradation Provisions*, from which an excerpt is provided:

314 CMR 4.04(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.

314 CMR 4.04(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.

314 CMR 4.04(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: *401 Water Quality Certification for Discharge of Dredged or Fill Material, Dredging, and Dredged Material Disposal in Waters of the United States within the Commonwealth* 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

314 CMR 4.04(4) _Protection of Special Resource Waters_. The quality of Special Resource Waters shall be protected and maintained. No new or increased discharge to an SRW, 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).

314 CMR 4.04(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: *Public Notice and Comment*. 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.

314 CMR 4.04(6): The Department applies its Antidegradation Implementation Procedures to point source discharges subject to 314 CMR 4.00.

314 CMR 4.04(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 314 CMR 3.00: *Surface Water Discharge Permit Program*. Before authorizing a discharge, all appropriate public participation and intergovernmental coordination shall be conducted in accordance with 314 CMR 2.00: *Permit Procedures*.

Appendix B: Summary of the Nitrogen Concentrations in Wellfleet Harbor Estuarine System

Table B-1: Summary of the Nitrogen Concentrations for the Wellfleet Harbor Estuarine System (Reprinted from Table VI-1 of the MEP Technical Report, Howes *et al*, 2017)

Measured data and modeled nitrogen concentrations for the Wellfleet Harbor estuarine system used in the model calibration plots of Figures VI-2 and VI-3. All concentrations are given in mg/L N. "Data mean" values are calculated as the average of all measurements. Data represented in this table were collected in the summers between 2003 and 2011.

Sub-Embayment	MEP monitoring station	data mean	s.d. all data	N	model min	model max	model average
Lower Wellfleet Harbor	WH-1	0.485	0.170	102	0.42	0.50	0.45
Lower Wellfleet Harbor	WH-2	0.511	0.160	113	0.42	0.52	0.47
Wellfleet Harbor by Audubon	WH-3	0.542	0.158	213	0.46	0.49	0.48
Mid Wellfleet Harbor	WH-4	0.539	0.147	160	0.45	0.59	0.51
Upper Wellfleet Harbor	WH-5	0.547	0.152	84	0.49	0.64	0.55
Lower Blackfish Creek	WH-6	0.618	0.170	79	0.48	0.55	0.52
Upper Blackfish Creek	WH-7	0.638	0.126	20	0.50	0.56	0.53
The Gut	WH-8	0.722	0.168	32	0.53	0.71	0.60
Herring River the Gut	WH-9	0.741	0.214	74	0.61	0.90	0.73
Outer Cove	WH-10	0.762	0.213	116	0.55	0.80	0.64
The Cove	WH-11	0.849	0.231	122	0.59	1.05	0.76
Duck Creek	WH-12	0.908	0.234	78	0.64	1.89	0.93

Appendix C: Stormwater Loading Information

Table C-1: The Wellfleet Harbor Estuarine System estimated waste load allocation (WLA) from runoff of all impervious areas within 200 feet of its waterbodies.

Estuary System Name	Watershed Impervious Area in 200 ft Buffer of Embayment Waterbody (acres)[1]	Total Watershed Impervious Area (acres)[2]	Watershed Impervious Area in 200 ft buffer as % of Total Watershed Impervious Area	MEP Total Unattenuated Watershed Impervious Load (kg/day)[2]	MEP Total Unattenuated Watershed Load (kg/day)[3]	Watershed Impervious buffer (200 ft) WLA (kg/day)[4]	Watershed buffer area WLA as percentage of MEP Total Unattenuated Watershed Load[5]
Herring River/ The Gut	4.3	296.3	1.5%	1.55	30.28	0.02	0.07
Duck Creek	10.8	67.5	15.9%	0.41	5.52	0.07	1.19
The Cove	19.2	129.2	14.8%	0.60	9.83	0.09	0.91
Drummer/Blackfish	15.7	87.4	17.9%	0.54	7.36	0.10	1.31
Hatches Creek	16.7	151.7	11.0%	0.68	9.57	0.07	0.78
Wellfleet Harbor	36.3	176.4	20.6%	1.03	17.53	0.21	1.21
Loagy Bay	8.0	29.4	27.3%	0.15	2.45	0.04	1.68
Total	110.9	937.8	11.8%	4.96	82.55	0.59	0.71

1. The entire impervious area within a 200 foot buffer zone around all waterbodies as calculated by MassGIS. 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 waste load allocation (WLA) it was assumed that all impervious surfaces within 200 feet of the shoreline discharge directly to the waterbody.
2. Total impervious load for the watershed was obtained from SMAST N load data files.
3. This includes the unattenuated nitrogen loads from wastewater from septic systems, landfill, wastewater treatment facilities, agriculture, fertilizer, runoff from impervious and natural surfaces and atmospheric deposition to freshwater waterbodies. This does not include direct atmospheric deposition to the estuary surface.
4. The impervious subwatershed 200 ft buffer area (acres) divided by total watershed impervious area (acres) then multiplied by total impervious subwatershed load (kg/day).
5. The impervious subwatershed buffer area WLA (kg/day) divided by the total subwatershed load (kg/day) then multiplied by 100.

Appendix D: Wellfleet Harbor Total Nitrogen TMDLs

Table D-1: TMDLs for Wellfleet Harbor Estuarine System – Two Total Nitrogen TMDLs and Five Protective TMDLs

Waterbody Name	Segment ID	Impairment	TMDL Type	TMDL (kg/day)	Notes
Wellfleet Harbor	MA96-34	Nutrient/Eutrophication Biological Indicators	Restoration	217.16	Includes portions identified by MEP as Drummer Cove and The Cove
Herring River	MA96-33	Aluminum, Estuarine Bioassessments, pH (low)	Protection[1]	48.64	
Duck Creek	MA96-32	Nutrient/Eutrophication Biological Indicators	Restoration	70.6	Includes portions identified MEP as The Cove
Blackfish Creek	MA96-123		Protection[3]	0.37	
Fresh Brook	MA96-126		Protection[3]	3.81	The MEP consolidated this waterbody with Hatches Creek in the model. Fresh Brook represents approximately 39.6% of the present watershed loading identified as Hatches Creek in the MEP model. The TMDL load for this waterbody has been prorated to represent the relative present watershed load (ie 39.6% of 9.61 kg/day)

Waterbody Name	Segment ID	Impairment	TMDL Type	TMDL (kg/day)	Notes
Hatches Creek	MA96-124		Protection[3]	5.80	The MEP consolidated this waterbody with Fresh Brook in the model. Fresh Brook represents approximately 60.4% of the present watershed loading identified as Hatches Creek in the MEP model. The TMDL load for this waterbody has been prorated to represent the relative present watershed load for Hatches Creek as a separate entity (ie 60.4% of 9.61 kg/day)
Loagy Bay	MA96-125	Chlorophyll *a*, Dissolved Oxygen	Restoration	10.83	
Wellfleet Harbor (total system)				**357.17**	

[1]Protective TMDL assigned based on hydraulic connection to Wellfleet Harbor. TMDL or Alternative Plan, for Herring River restoration to be developed separately.

[2] Not impaired for nutrients, but TMDL needed since embayments are hydrologically linked. (Also referred to as a Pollution Prevention TMDL.)