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Massachusetts Department of Environmental Protection

Massachusetts Estuaries Project

Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Phinneys Harbor, Eel Pond and the Back River System Bourne, Massachusetts

Executive Summary

1. Background

This report presents the results generated from the implementation of the Massachusetts Estuaries Project's Linked Watershed-Embayment Approach to the Phinneys Harbor, Eel Pond and Back River embayment system, a coastal embayment within the Town of Bourne, Massachusetts. Analyses of the Phinneys Harbor, Eel Pond and Back River embayment system was performed to assist the Town with up-coming nitrogen management decisions associated with the Towns' current and future wastewater planning and management efforts, as well as wetland restoration, anadromous fish runs, shell fishery, open-space, and harbor maintenance programs. As part of the MEP approach, habitat assessment was conducted on the embayment based upon available water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure. Nitrogen loading thresholds for use as goals for watershed nitrogen management are the major product of the MEP effort. In this way, the MEP offers a science-based management approach to support the Town of Bourne resource planning and decision-making process. The primary products of this effort are: (1) a current quantitative assessment of the nutrient related health of the Phinneys Harbor, Eel Pond and Back River embayment, (2) identification of all nitrogen sources (and their respective N loads) to embayment waters, (3) nitrogen threshold levels for maintaining Massachusetts Water Quality Standards within embayment waters, (4) analysis of watershed nitrogen loading reduction to achieve the N threshold concentrations in embayment waters, and (5) a functional calibrated and validated Linked Watershed-Embayment modeling tool that can be readily used for evaluation of nitrogen management alternatives (to be developed by the Town) for the restoration of the Phinneys Harbor, Eel Pond and Back River embayment system.

Wastewater Planning: As increasing numbers of people occupy coastal watersheds, the associated coastal waters receive increasing pollutant loads. Coastal embayments throughout the Commonwealth of Massachusetts (and along the U.S. eastern seaboard) are becoming nutrient enriched. The elevated nutrients levels are primarily related to the land use impacts associated with the increasing population within the coastal zone over the past half-century.

The regional effects of both nutrient loading and bacterial contamination span the spectrum from environmental to socio-economic impacts and have direct consequences to the culture, economy, and tax base of Massachusetts's coastal communities. The primary nutrient causing the increasing impairment of our coastal embayments is nitrogen, with its primary sources being wastewater disposal, and nonpoint source runoff that carries nitrogen (e.g. fertilizers) from a range of other sources. Nitrogen related water quality decline represents one of the most serious threats to the ecological health of the nearshore coastal waters. Coastal embayments, because of their shallow nature and large shoreline area, are generally the first coastal systems to show the effect of nutrient pollution from terrestrial sources.

In particular, the Phinneys Harbor, Eel Pond and Back River embayment system within the Town of Bourne is at risk of eutrophication (over enrichment) from enhanced nitrogen loads entering through groundwater and surface water from the increasingly developed watershed to this coastal system. Eutrophication is a process that occurs naturally and gradually over a period of tens or hundreds of years. However, human-related (anthropogenic) sources of nitrogen may be introduced into ecosystems at an accelerated rate that cannot be easily absorbed, resulting in a phenomenon known as cultural eutrophication. In both marine and freshwater systems, cultural eutrophication results in degraded water quality, adverse impacts to ecosystems, and limits on the use of water resources.

The Town of Bourne has recognized the severity of the problem of eutrophication and the need for watershed nutrient management. To that end, the Town of Bourne and work groups have recognized that a rigorous scientific approach yielding site-specific nitrogen loading targets is required for sound decision-making and alternatives analysis relative to watershed nutrient management for the protection and/or restoration of the Phinneys Harbor, Eel Pond and Back River system. The conduct of this multi-step process has taken place under the programmatic umbrella of the Massachusetts Estuaries Project, which is a partnership effort between all MEP collaborators and the Town. The modeling tools developed as part of this program provide the quantitative information necessary for the Towns' nutrient management groups to predict the impacts on water quality from a variety of proposed management scenarios.

Nitrogen Loading Thresholds and Watershed Nitrogen Management: Realizing the need for scientifically defensible management tools has resulted in a focus on determining the aquatic system's assimilative capacity for nitrogen. The highest-level approach is to directly link the watershed nitrogen inputs with embayment hydrodynamics to produce water quality results that can be validated by water quality monitoring programs. This approach when linked to state-of-the-art habitat assessments yields accurate determination of the "allowable N concentration increase" or "threshold nitrogen concentration". These determined nitrogen concentrations are then directly relatable to the watershed nitrogen loading, which also accounts for the spatial distribution of the nitrogen sources, not just the total load. As such, changes in nitrogen load from differing parts of the embayment watershed can be evaluated relative to the degree to which those load changes drive embayment water column nitrogen concentrations toward the "threshold" for the embayment system. To increase certainty, the "Linked" Model is independently calibrated and validated for each embayment.

Massachusetts Estuaries Project Approach: The Massachusetts Department of Environmental Protection (MassDEP), the University of Massachusetts – Dartmouth School of Marine Science and Technology (SMAST), and others including the Cape Cod Commission

(CCC) have undertaken the task of providing a quantitative tool to communities throughout southeastern Massachusetts (the Linked Watershed-Embayment Management Model) for nutrient management in their coastal embayment systems. Ultimately, use of the Linked Watershed-Embayment Management Model tool by municipalities in the region results in effective screening of nitrogen reduction approaches and eventual restoration and protection of valuable coastal resources. The MEP provides technical guidance in support of policies on nitrogen loading to embayments, wastewater management decisions, and establishment of nitrogen Total Maximum Daily Loads (TMDLs). A TMDL represents the greatest amount of a pollutant that a waterbody can accept and still meet water quality standards for protecting public health and maintaining the designated beneficial uses of those waters for drinking, swimming, recreation and fishing. The MEP modeling approach assesses available options for meeting selected nitrogen goals that are protective of embayment health and achieve water quality standards.

The core of the Massachusetts Estuaries Project analytical method is the Linked Watershed-Embayment Management Modeling Approach, which links watershed inputs with embayment circulation and nitrogen characteristics.

The Linked Model builds on well-accepted basic watershed nitrogen loading approaches such as those used in the Buzzards Bay Project, the CCC models, and other relevant models. However, the Linked Model differs from other nitrogen management models in that it:

- requires site-specific measurements within each watershed and embayment;
- uses realistic “best-estimates” of nitrogen loads from each land-use (as opposed to loads with built-in “safety factors” like Title 5 design loads);
- spatially distributes the watershed nitrogen loading to the embayment;
- accounts for nitrogen 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 nitrogen regenerated within the embayment;
- is validated by both independent hydrodynamic, nitrogen concentration, and ecological data;
- is calibrated and validated with field data prior to generation of “what if” scenarios.

The Linked Model Approach’s greatest assets are its ability to be clearly calibrated and validated, and its utility as a management tool for testing “what if” scenarios for evaluating watershed nitrogen management options.

For a comprehensive description of the Linked Model, please refer to the *Full Report: Nitrogen Modeling to Support Watershed Management: Comparison of Approaches and Sensitivity Analysis*, available for download at http://www.state.ma.us/dep/smerp/smerp.htm. A more basic discussion of the Linked Model is also provided in Appendix F of the *Massachusetts Estuaries Project Embayment Restoration Guidance for Implementation Strategies*, available for download at http://www.state.ma.us/dep/smerp/smerp.htm. The Linked Model suggests which management solutions will adequately protect or restore embayment water quality by enabling towns to test specific management scenarios and weigh the resulting water quality impact against the cost of that approach. In addition to the management scenarios modeled for this report, the Linked Model can be used to evaluate additional management scenarios and may be updated to reflect future changes in land-use within an embayment watershed or changing embayment characteristics. In addition, since the Model uses a holistic approach (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. Unlike many approaches, the Linked Model accounts for nutrient sources, attenuation, and recycling and variations in tidal hydrodynamics and accommodates the spatial distribution of these processes. For an overview of several management scenarios that may be employed to restore embayment water quality, see *Massachusetts Estuaries Project Embayment Restoration Guidance for Implementation Strategies*, available for download at http://www.state.ma.us/dep/smerp/smerp.htm.

Application of MEP Approach: The Linked Model was applied to the Phinneys Harbor, Eel Pond and Back River embayment system by using site-specific data collected by the MEP and water quality data from the Coalition for Buzzards Bay Water Quality Monitoring Program (see Chapter 2). Evaluation of upland nitrogen loading was conducted by the MEP, data was provided by the Town of Bourne Planning Department, and watershed boundaries delineated by USGS. This land-use data was used to determine watershed nitrogen loads within the Phinneys Harbor, Eel Pond and Back River embayment system and the systems sub-embayments as appropriate (current and build-out loads are summarized in Table IV-3). Water quality within a sub-embayment is the integration of nitrogen loads with the site-specific estuarine circulation. Therefore, water quality modeling of this tidally influenced estuary included a thorough evaluation of the hydrodynamics of the estuarine system. Estuarine hydrodynamics control a variety of coastal processes including tidal flushing, pollutant dispersion, tidal currents, sedimentation, erosion, and water levels. Once the hydrodynamics of the system was quantified, transport of nitrogen was evaluated from tidal current information developed by the numerical models.

A two-dimensional depth-averaged hydrodynamic model based upon the tidal currents and water elevations was employed for the Phinneys Harbor, Eel Pond and Back River embayment system. Once the hydrodynamic properties of the estuarine system were computed, two-dimensional water quality model simulations were used to predict the dispersion of the nitrogen at current loading rates. Using standard dispersion relationships for estuarine systems of this type, the water quality model and the hydrodynamic model was then integrated in order to generate estimates regarding the spread of total nitrogen from the site-specific hydrodynamic properties. The distributions of nitrogen loads from watershed sources were determined from land-use analysis while nitrogen entering Bourne's coastal embayment was quantified by direct measurement of stream nutrient concentrations and freshwater flow, predominantly groundwater, in streams discharging directly to the embayment. Boundary nutrient concentrations in Buzzards Bay source waters were taken from water quality monitoring data. Measurements of current salinity distributions throughout the estuarine waters of the Phinneys Harbor, Eel Pond and Back River embayment system was used to calibrate the water quality model, with validation using measured nitrogen concentrations (under existing loading conditions). The underlying hydrodynamic model was calibrated and validated independently using water elevations measured in time series throughout the embayments.

MEP Nitrogen Thresholds Analysis: The threshold nitrogen level for an embayment represents the average water column concentration of nitrogen that will support the habitat quality being sought. The water column nitrogen level is ultimately controlled by the watershed nitrogen load and the nitrogen concentration in the inflowing tidal waters (boundary condition). The water column nitrogen concentration is modified by the extent of sediment regeneration. Threshold nitrogen levels for the embayment systems in this study were developed to restore or maintain SA waters or high habitat quality. High habitat quality was defined as supportive of eelgrass and infaunal communities. Dissolved oxygen and chlorophyll a were also considered in the assessment.

The nitrogen thresholds developed in Section VIII-2 of this report were used to determine the amount of total nitrogen mass loading reduction required for restoration of eelgrass and infaunal habitats in the Phinneys Harbor, Eel Pond and Back River system. Tidally averaged total nitrogen thresholds derived in Section VIII.1 were used to adjust the calibrated constituent transport model developed in Section VI. Watershed nitrogen loads were sequentially lowered, using reductions in septic effluent discharges only, until the nitrogen levels reached the threshold level at the sentinel station (Phinneys Harbor, PH-4) chosen for Phinneys Harbor, Eel Pond and Back River. It is important to note that load reductions can be produced by reduction of any or all sources or by increasing the natural attenuation of nitrogen within the freshwater systems to the embayment. The load reductions presented in the report represent only one of a suite of potential reduction approaches that need to be evaluated by the community. The presentation in this report of load reductions aims to establish the general degree and spatial pattern of reduction that will be required for restoration of this nitrogen impaired embayment.

The Massachusetts Estuaries Project's thresholds analysis, as presented in this technical report, provides the site-specific nitrogen reduction guidelines for nitrogen management of the Phinneys Harbor, Eel Pond and Back River embayment system in the Town of Bourne. Future water quality modeling scenarios should be run which incorporate the spectrum of strategies that result in nitrogen loading reduction to the embayment. The MEP analysis has initially focused upon nitrogen loads from on-site septic systems as a test of the potential for achieving the level of total nitrogen reduction for restoration of the embayment system.

2. Problem Assessment (Current Conditions)

The Phinneys Harbor System is a complex estuary composed of 3 component basins: a large embayment (Phinneys Harbor), a small drowned kettle pond (Eel Pond) and a tidal salt marsh (Back River). Each of these 3 basins has different natural sensitivities to nitrogen enrichment and organic matter loading. Evaluation of habitat quality must consider the natural structure of each system and the types of eelgrass habitat and infaunal communities that they naturally support. A habitat assessment was conducted throughout Phinneys Harbor, Eel Pond and Back River based upon available water quality monitoring data, historical changes in eelgrass distribution, time-series water column oxygen measurements, and benthic community structure. At present, the Phinneys Harbor System is showing variations in nitrogen enrichment among its 3 principal component basins. The inner basins of Eel Pond and Back River are clearly nitrogen enriched over Phinneys Harbor and Phinneys Harbor is clearly enriched over the adjacent Buzzards Bay waters. The evaluation of habitat quality within each of these 3 basins was based upon the level of nitrogen enrichment, resultant oxygen depletion and chlorophyll enhancement, eelgrass and infaunal indicators. Moreover, the evaluation of habitat quality was made relative to the ecology of each specific basin. The results indicate a system currently supportive of healthy infaunal habitat for the salt marsh basin of Back River, the kettle basin of Eel Pond and the outer basin of Phinneys Harbor. However, the Phinneys Harbor basin must be classified as impaired as a result of its virtual total loss of eelgrass habitat over the past 10-15 years.

Overall, the oxygen levels within the 3 major sub-basins to the Phinneys Harbor System are not showing significant impairment when their physical structure and natural biogeochemical cycling is considered. Similar to other embayments in southeastern Massachusetts, the Back River and Eel Pond portions of the Phinneys Harbor system evaluated in this assessment showed high frequency variation, apparently related to diurnal and sometimes tidal influences. The dissolved oxygen records indicate that Eel Pond is nitrogen enriched, but the oxygen depletion was generally to the 4-5 mg/L level, consistent with the chlorophyll average of 11.8 ug/L. Similarly, the Back River also showed oxygen depletion consistent with its function as a salt marsh. Both inner basins showed greater nitrogen enrichment and subsequent oxygen depletions and chlorophyll levels than for the outer basin of Phinneys Harbor. However, the cause of these conditions appears to stem primarily from the naturally organic enriched nature of salt marshes (Back River) and the structure of the drowned kettle pond, Eel Pond (2-3 m deep). At present nitrogen enrichment to Eel Pond appears related to its nature as a depositional basin, as removal of anthropogenic nitrogen inputs in the Linked Watershed-Embayment Model did little to lower watercolumn nitrogen levels (Chapter VI, VIII). Given the relatively low watershed nitrogen loading (Chapter IV) and the minor change in predicted nitrogen levels with removal of anthropogenic sources (modeled, Chapters VI, VIII), it appears that this is predominantly "natural" condition and is consistent with the absence of eelgrass in the 1951 survey (Section VII.3) and relatively healthy infaunal habitat (Section VII.4).

The Phinneys Harbor Estuary is moderately deep compared to others along the south shore of Cape Cod and even nearby West Falmouth Harbor. However, water depths are well within the range for eelgrass growth in Massachusetts, given suitable conditions of light penetration. The eelgrass surveys reviewed for this threshold analysis indicated that eelgrass habitat within this estuary is limited to the Phinneys Harbor basin as there is no evidence that eelgrass has colonized either Eel Pond or Back River. At present there is virtually no eelgrass habitat within the Phinneys Harbor System at a tidally averaged total nitrogen level for the Harbor basin of 0.36 mg N/L, higher than the 0.35 threshold for eelgrass in nearby West Falmouth Harbor, with even higher total nitrogen levels in the inner nearshore areas. The temporal surveys indicate that eelgrass habitat loss in Phinneys Harbor is a relatively recent phenomenon. The decline of eelgrass beds appears to have occurred primarily between 1985 and 1995 and continued to 2001. The current absence of eelgrass throughout Phinneys Harbor is consistent with the depth of the basin and the chlorophyll levels of 5-10 ug/L as measured by the BayWatcher Program (Howes et al. 1998). The timing of the eelgrass habitat loss is also consistent with changes in land-use within the watershed. In addition, the spatial pattern of bed loss is consistent with the typical pattern of habitat decline related to increasing nitrogen loading from a watershed. Based on the available data (1951, 1985) it appears that the total area of impaired eelgrass habitat within the Phinneys Harbor basins is approximately 70-80 acres. Although Phinneys Harbor presently supports healthy infaunal habitat (tolerant of higher levels of enrichment), it appears to have become sufficiently nutrient enriched to impair its eelgrass habitat.

The infaunal study indicated an overall system supporting generally healthy infaunal habitat relative to the ecosystem types represented. Evaluation of infaunal habitat quality considered the natural structure of each system relative to the type of infaunal communities that they support. Overall, Phinneys Harbor basin is presently supporting a healthy infaunal habitat. Six of the eleven sites supported infaunal communities of 20-25 species and ~250 or more individuals. Diversity and eveness were excellent, generally >2.5 and >0.65, respectively. The 5 locations sampled with lower species and population counts were generally within present or historic deep channels (PNH 2,3,4,10) with one station located in an area of gravels (PNH 9). The community was dominated by mollusks and crustaceans (40 species total) with polychaetes comprising 44% or 31 of the total species observed. Deep burrowing forms were common.

Eel Pond and Back River also showed healthy to moderately healthy infaunal habitat relative to the ecosystem type. The Back River marshes support healthy infaunal habitat, with ~10 species per sample, but high numbers of individuals (500-1500), with high diversity and Eveness (H'= 2.1 – 2.7; E >0.66). The population was dominated by *Gemma* (a small bivalve), and polychaetes (Hesonids and Capitellids). The presence of the organic enrichment indicator, *Capitella capitata* (16% of individuals) reflects the natural organic enrichment of these systems.

In contrast to Back River, Eel Pond is a drowned kettle pond which is sensitive to nitrogen enrichment that can result in organic matter accumulation and oxygen depletion (Section VII.2). Consistent with its generally good oxygen condition, Eel Pond is presently supportive of a healthy to moderately healthy infaunal habitat. Both the species numbers (11-17) and numbers of individuals (650-1900) indicate a productive benthic animal community dominated by hesonids (carnivorous polychaetes) and Gemma (small bivalve), which small polychaetes also being important (*Streblospio, Capitella, Carezziella*). The diversity and eveness indices were indicative of a healthy environment being 2.2-3.1 and 0.64-0.84, respectively. Mollusks and crustaceans accounted for 34% of the species and deeper burrowing forms were observed.

The overall results indicate a system generally supportive of diverse and healthy communities appropriate to each of the 3 component basin types. The infaunal habitat quality within each of the 3 basins of the Phinneys Harbor System is fully consistent with the oxygen and chlorophyll measurements, temporal trend in eelgrass (i.e. only recent loss from outer basin) and relatively low tidally averaged total nitrogen concentration for each basin, ranging from 0.45 mg N/L in Eel Pond, 0.42 mg N/L in Back River to 0.36 in Phinneys Harbor (basin average). These levels compare well to the levels supportive of healthy infauna found in West Falmouth Harbor (main basin) of 0.38 mg N/L and in enclosed basins along Nantucket Sound (e.g. Perch Pond, Bournes Pond, Popponesset Bay) where levels <0.5 mg N/L were found to be supportive of healthy infaunal habitat.

3. Conclusions of the Analysis

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

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

Watershed nitrogen loads (Tables ES-1 and ES-2) for the Town of Bourne Phinneys Harbor, Eel Pond and Back River embayment system was comprised primarily of wastewater nitrogen. Land-use and wastewater analysis found that generally about 70%-90% of the controllable watershed nitrogen load to the embayment was from wastewater.

A major finding of the MEP clearly indicates that a single total nitrogen threshold can not be applied to Massachusetts' estuaries, based upon the results of the Great, Green and Bournes Pond Systems, Popponesset Bay System, the Hamblin / Jehu Pond / Quashnet River analysis in eastern Waquoit Bay and the Pleasant Bay and Nantucket Sound embayments associated with the Town of Chatham. This is almost certainly going to be true for the other embayments within the MEP area, as well.

The threshold nitrogen levels for the Phinneys Harbor, Eel Pond and Back River embayment system in Bourne were determined as follows:

Phinneys Harbor, Eel Pond and Back River Threshold Nitrogen Concentrations

- The Phinneys Harbor System is presently supportive of infaunal habitat throughout its 3 main basins, but is clearly impaired by nitrogen enrichment in the largest component basin of Phinneys Harbor. Given the documented importance of eelgrass habitat to this outer basin and the virtual loss of all 88 acres of eelgrass that it historically supported, eelgrass restoration in this basin was set as the primary nitrogen management goal for the overall System. Based upon the eelgrass habitat restoration objective and the distribution of total nitrogen within the Harbor basin, most appropriate sentinel station is PH-4, as lowering TN levels at this station will also result in even lower levels at the other stations in the outer basin.

- The threshold level to restore eelgrass within the outer basin of Phinneys Harbor was set at 0.35 mg N/L based upon the detailed quantitative analysis of nearby West Falmouth Harbor where both temporal nitrogen and eelgrass distribution trends could be assessed as well as comparative analysis of total nitrogen levels within healthy eelgrass beds. This threshold TN level is supported by site-specific factors from the Phinneys Harbor basin:

(a) at present there is virtually no eelgrass habitat within the Phinneys Harbor System at a tidally averaged TN level for the Harbor basin of 0.36 mgN/L;

(b) the present absence of eelgrass is at a tidally averaged TN level for the sentinel station of 0.37 mgN/L;

(c) the outer basin has only recently lost its eelgrass habitat and still supports healthy infaunal habitat, suggesting that it is only slightly over its nitrogen threshold level;

- The target nitrogen concentration (tidally averaged TN) for restoration of eelgrass at the sentinel location within the Phinneys Harbor System was determined to be 0.35 mg TN L^{-1}. This nitrogen level is lower than found for other complex systems such as Stage Harbor (0.38 N/L^{-1}) and analysis of nitrogen levels within the eelgrass bed in Waquoit Bay, near the inlet (measured TN of 0.395 mg N L^{-1}, tidally corrected <0.38 mg N L^{-1}), and (3) a similar analysis in Bournes Pond. The sentinel station under present loading conditions supports a tidally corrected average concentration of 0.37 mg TN L^{-1}, so a watershed nitrogen management will be required for restoration of the estuarine habitats within this system. It must be stressed that the nitrogen threshold for the Phinneys Harbor Estuary is at the sentinel location. A secondary criteria for infauna (discussed in Chapter VIII) should be met when the threshold is met at the sentinel station used for setting the nitrogen threshold for the Phinneys Harbor basin and serve as a “check”. .

It is important to note that the analysis of future nitrogen loading to the Phinneys Harbor, Eel Pond and Back River estuarine system focuses upon additional shifts in land-use from forest/grasslands to residential and commercial development. However, the MEP analysis indicates that significant increases in nitrogen loading can occur under present land-uses, due to shifts in occupancy, shifts from seasonal to year-round usage and increasing use of fertilizers (presently less than half of the parcels use lawn fertilizers). Therefore, watershed-estuarine nitrogen management must include management approaches to prevent increased nitrogen loading from both shifts in land-uses (new sources) and from loading increases of current land-uses. The overarching conclusion of the MEP analysis of the Phinneys Harbor, Eel Pond and Back River estuarine system is that restoration will necessitate a reduction in the present (2005) nitrogen inputs and management options to negate additional future nitrogen inputs.

Table ES-1. Existing total and sub-embayment nitrogen loads to the estuarine waters of the Phinneys Harbor and Back River estuary systems, observed nitrogen concentrations, and sentinel system threshold nitrogen concentrations.

Sub-embayments	Natural Background Watershed Load [1] (kg/day)	Present Land Use Load [2] (kg/day)	Present Septic System Load (kg/day)	Present WWTF Load [3] (kg/day)	Present Watershed Load [4] (kg/day)	Direct Atmospheric Deposition [5] (kg/day)	Present Net Benthic Flux (kg/day)	Present Total Load [6] (kg/day)	Observed TN Conc. [7] (mg/L)	Threshold TN Conc. (mg/L)
BACK RIVER SYSTEM										
Phinneys Harbor	1.252	2.143	12.608	0.00	14.751	5.186	15.525	35.462	0.53-0.28	--
Back River	1.406	4.477	5.186	0.00	9.663	0.929	1.538	12.131	--	--
Eel Pond	0.411	0.644	4.244	0.00	4.888	0.246	-0.709	4.425	0.64-0.30	--
Back River System Total	**3.07**	**7.264**	**22.038**	**0.00**	**29.302**	**6.361**	**16.354**	**52.017**	**0.64-0.28**	**0.350**[8]

1 assumes entire watershed is forested (i.e., no anthropogenic sources)
2 composed of non-wastewater loads, e.g. fertilizer and runoff and natural surfaces and atmospheric deposition to lakes
3 existing wastewater treatment facility discharges to groundwater
4 composed of combined natural background, fertilizer, runoff, and septic system loadings
5 atmospheric deposition to embayment surface only
6 composed of natural background, fertilizer, runoff, septic system atmospheric deposition and benthic flux loadings
7 average of 1992 – 2005 data, ranges show the upper to lower regions (highest-lowest) of an sub-embayment. Individual yearly means and standard deviations in Table VI-1.
8 Threshold for sentinel site located in Phinney's Harbor at water quality station PH4.

Table ES-2. Present Watershed Loads, Thresholds Loads, and the percent reductions necessary to achieve the Thresholds Loads for the Ashumet Valley embayment systems (Great, Green and Bournes Ponds), Towns of Falmouth, Massachusetts.

Sub-embayments	Present Watershed Load [1] (kg/day)	Target Threshold Watershed Load [2] (kg/day)	Direct Atmospheric Deposition (kg/day)	Benthic Flux Net [3] (kg/day)	TMDL [4] (kg/day)	Percent watershed reductions needed to achieve threshold load levels
BACK RIVER SYSTEM						
Phinneys Harbor	14.751	4.694	5.186	12.165	22.045	-68.2%
Back River	9.663	9.663	0.929	1.538	12.131	0.00%
Eel Pond	4.888	4.888	0.246	-0.709	4.425	0.00%
Back River System Total	**29.302**	**19.245**	**6.361**	**12.994**	**38.601**	**-68.2%**

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