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Massachusetts Department of Environmental Protection

Massachusetts Estuaries Project

Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Oyster Pond Falmouth, 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 Oyster Pond embayment system, a coastal embayment within the Town of Falmouth, Massachusetts. Analyses of the Oyster Pond embayment system was performed to assist the Town with up-coming nitrogen management decisions associated with the Towns' current and future wastewater planning 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 Falmouth 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 Oyster Pond 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 Oyster Pond 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 Oyster Pond embayment system within the Town of Falmouth is at risk of eutrophication (over enrichment) from enhanced nitrogen loads entering through groundwater and surface water from the increasingly developed watersheds to these coastal salt ponds. 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 Falmouth has recognized the severity of the problem of eutrophication and the need for watershed nutrient management and is currently developing a Comprehensive Wastewater Management Plan, which it plans to rapidly implement. The Town of Falmouth has also completed and implemented wastewater planning in other regions of the Town not associated with the Oyster Pond embayment system. The Town has nutrient management activities related to their tidal embayments, which have been associated with the MEP effort in Great/Perch Pond, Green Pond and Bournes Pond embayment systems as well as other embayments in the Town of Falmouth such as Little Pond and West Falmouth Harbor. The Town of Falmouth and work groups have recognized that a rigorous scientific approach yielding site-specific nitrogen loading targets was required for decision-making and alternatives analysis. The completion 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 (DEP), 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 Oyster Pond embayment system by using site-specific data collected by the MEP and water quality data from the Falmouth PondWatch Program (see Chapter 2). Evaluation of upland nitrogen loading was conducted by the MEP, data was provided by the Town of Falmouth Planning Department, and watershed boundaries delineated by USGS. This land-use data was used to determine watershed nitrogen loads within the Oyster Pond embayment system and each 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 controlled 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. In Oyster Pond, the hydrodynamic regime is dominated by freshwater inputs to the system from groundwater recharge, surface flow run-off from the watershed, and direct precipitation to the pond's surface. Though tides in Vineyard Sound are only occasionally high enough to cause seawater flows into the pond, tidal flushing is still important to the stability and health of this estuary, mostly by its effect on salinity in the pond. Once the hydrodynamics of the system was quantified, transport of nitrogen was evaluated from 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 Oyster Pond embayment system. The hydrodynamic modeling effort for Oyster Pond was similar to other estuarine systems modeled as part of the MEP, though the tidally restricted nature of this system required modifications to the modeling and analysis techniques that have been applied to simpler embayments. From the perspective of hydrodynamics, the most important difference between the Oyster Pond system and other estuaries in Falmouth is the adjustable salinity control/fish weir in the inlet channel to the Pond.

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 Falmouth'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 Vineyard Sound source waters were taken from water quality monitoring data. Measurements of current salinity distributions throughout the estuarine waters of the Oyster Pond 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 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 nitrogen level are determined, the Linked Watershed-Embayment Model is used to sequentially adjust nitrogen loads until the targeted nitrogen concentration is achieved.

Oyster Pond differs from most other estuaries in its lack of horizontal gradients in salinity, nitrogen, and nitrogen related parameters (chlorophyll a, D.O., transparency, etc.). Therefore, selection of the sentinel station was not based on horizontal gradients and their response to changing nitrogen loads. Instead, the sentinel station was selected to best capture the overall conditions of the Pond waters.

The nitrogen thresholds developed in Section VIII-2 were used to determine the amount of total nitrogen mass loading reduction required for restoration of Oyster Pond to a series of dissolved oxygen values. Due to the existing salinity levels in the Pond (historically between 0 and 4 ppt), eelgrass cannot be established within this brackish water body. Instead, development of an appropriate threshold to restore infaunal habitat was based on minimum dissolved oxygen within the lower basin of Oyster Pond. It was determined that a linear relationship was appropriate to assess the expected changes in dissolved oxygen relative to total nitrogen for the site-specific conditions within the main basin of the Pond. Minimum dissolved oxygen thresholds derived in Section VIII.1 were used to adjust the calibrated constituent transport model developed in Section VI. 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 Oyster Pond embayment system in the Town of Falmouth. 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 each embayment system. The concept was that since septic system nitrogen loads generally represent 75%-85% of the watershed load to the Oyster Pond embayment system and are more manageable than other of the nitrogen sources, the ability to achieve needed reductions through this source is a good gauge of the feasibility for restoration of these systems.

2. Problem Assessment (Current Conditions)

A habitat assessment was conducted throughout Oyster Pond based upon available water quality monitoring data, macroalgae distribution, time-series water column oxygen measurements, and benthic community structure. At present the bulk of the Oyster Pond is showing moderately to significantly impaired habitat quality. All of the indicators show a consistent pattern of moderate to significant impairment throughout the basins of Oyster Pond. While the Pond does not show strong gradients in salinity or water quality parameters, the enclosed nature of the northern basin appears to increase the duration of stratification and subsequent hypoxia. The deep southern basin (~6 m) is salinity stratified for months to years at a time and is generally anoxic as a result of this natural process. Based primarily on the infaunal communities and the bottom water hypoxia, it was concluded that Oyster Pond habitat is presently moderately to significantly impaired. Since the ultimate cause of the low dissolved oxygen ($\leq$4m) results from nitrogen enrichment, it can also be concluded that the system is nitrogen overloaded at present.

The following is a brief synopsis of the present habitat quality within the salt pond. The underlying quantitative data is presented on nitrogen (Section VI.1.3), oxygen and chlorophyll *a* (Section VII.2), eelgrass (Section VII.3), and benthic infauna (Section VII.4).

The effect of nitrogen enrichment is to cause oxygen depletion; however, with increased phytoplankton (or epibenthic algae) production, oxygen levels will rise in daylight to above atmospheric equilibration levels in shallow systems (generally ~7-8 mg L^{-1} at the mooring sites). The clear evidence of oxygen levels above atmospheric equilibration indicates that the upper tidal reach of the Oyster Pond System is eutrophic.

Unlike many of the other embayments in southeastern Massachusetts, Oyster Pond showed a relatively consistent pattern of low oxygen in its bottom waters throughout its basins. The deep, southern basin (6 meters) is consistently anoxic during summer months due to its salinity stratification which persists for months to years. However, this represents only ~10% of the pond bottom. The remaining areas, $\leq$4 meters depth are only periodically anoxic or hypoxic. The northern basin was periodically anoxic between1998-2004. However, this basin is enclosed and this anoxia is driven mainly by stratification. The majority of the sediments in the pond (~80%) are represented by the oxygen levels observed in the upper and lower main basin (OP-2 3.25 m, OP-3 4 m). These regions are more open to wind-driven mixing and showed oxygen levels 3 mg/L or above in 96% of samplings and 2 mg/L as a minimum level. Restoration of this system will require an improvement of oxygen levels in this lower basin, which represents most of the benthic habitat and which does not appear to support long periods of stratification shallower than 4 meters depth (as opposed to the northern basin)..

The low salinity waters of Oyster Pond are not supportive of eelgrass bed formation. The DEP Eelgrass Mapping Program has conducted no surveys in Oyster Pond. However, observations have been made by PondWatch from 1987 to present which support the lack of eelgrass in this system. Similarly, a complete system data collection and analysis effort conducted in the 1960’s throughout the main basin of Oyster Pond did not indicate the presence of eelgrass (Emery, 1997). This latter effort included a census of submerged aquatic vegetation, which did not indicate eelgrass, but did indicate that the dominant SAV in 2004, *Ceratophyllum demersum*, was also dominant in the 1960’s. Therefore, the most likely reason for the absence of eelgrass in the main basin of Oyster Pond is the low salinity. This indicates that eelgrass cannot be used as a habitat restoration indicator for this system.

The Benthic Infaunal Study indicated that Oyster Pond is not presently supportive of either diverse (H' 0-1.12, mean 0.65) or evenly distributed (mean E = 0.46) benthic infauna. More telling is the low number of species (0-6, mean=3) compared to nearby healthy estuarine areas (~30 species per sample). Due to its brackish waters, Oyster Pond sediments supported both freshwater and estuarine invertebrate populations. The freshwater species were generally insect larvae and these tended to dominate the community. Also notable was that almost half of the samples (5 of 11) had only 0-84 individuals, indicative of an impoverished community. Although the remaining samples had dense populations, they were distributed among a very few species, 6 or less, indicating a stressed community. Overall, the infauna community was consistent with the low dissolved oxygen and organic matter deposition observed in this relatively closed estuarine basin.

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 or dissolved oxygen conditions 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 due to ground or surface water flows and (in the case of Oyster pond limited flushing via tidal flows. The water column nitrogen concentration is modified by the extent of sediment regeneration and by direct atmospheric deposition.

The nitrogen threshold for Oyster Pond is based upon restoring benthic habitat for infaunal animals. Given the natural stratification of Pond waters, sediments < 4 meters depth representing ~80% of the pond bottom were targeted. This depth is based upon the depth distribution of the bottom and the depth of the mixed layer. Since the present nitrogen levels result in periodic hypoxia at 4 meters depth, the nitrogen threshold was set to improve and maintain oxygen levels $\geq$6 mg/L at 4 meters depth in the main basin (OP-3). At present, the minimum dissolved oxygen at this station is most likely 3 mg/L, although a single reading of 2 mg/L was recorded. Given the uncertainties in determining minimum D.O. in any estuary, the nitrogen threshold was set using 2 mg/L as the current minimum D.O. level.

Watershed nitrogen loads (Tables ES-1 and ES-2) for the Town of Falmouth Oyster Pond embayment system was comprised primarily of wastewater nitrogen. Land-use and wastewater analysis found that generally about 75%-85% of the watershed nitrogen load to the embayment was from wastewater.

The threshold nitrogen levels for the Oyster Pond embayment system in Falmouth were determined as follows:

Oyster Pond Threshold Criteria

- Since at summer temperatures (25^{o}C) and salinities (2 ppt), dissolved oxygen saturation is 8.2 mg/L and current oxygen minimum is 2 mg/L then raising the minimum oxygen level to 6 mg/L would require 4/6.2 or 65% reduction in the rate of oxygen uptake during stratification. This assumes that the present duration and frequency of stratification of waters overlying sediments 4 meters or less deep will remain as at present. This is a safe assumption as long as the management plan does not allow the pond salinity levels to climb above target 2-4 ppt range. Given the link between nitrogen load and oxygen uptake rate, this 65% reduction in oxygen uptake would require a 65% reduction in nitrogen loading to Oyster Pond. Using a similar analysis, raising the periodic minimum dissolved oxygen to 3.8 mg/L (Chesapeake Bay value) or the SB criteria of 5 mg/L would require reductions in nitrogen **loading** of 29% and 48%, respectively.

- As shown in Table VIII-2, the nitrogen load reductions within the system necessary to achieve the threshold dissolved oxygen concentrations were higher for higher minimum dissolved oxygen levels. Since the nitrogen concentrations are generally uniform across the entire surface of Oyster Pond (i.e. there is virtually no spatial gradient in nitrogen concentration), the nitrogen load was removed uniformly. Distributions of tidally-averaged nitrogen concentrations associated with the threshold analysis are shown in Section VIII.

- To achieve the threshold dissolved oxygen concentrations at the sentinel stations, a reduction in TN **concentration** of approximately 9%, 15%, and 21% is required for dissolved oxygen concentrations of 3.8 mg/l (based on the EPA's Chesapeake Bay limit), 5.0 mg/l (Massachusetts SB waters), and 6.0 mg/l (Massachusetts SA waters), respectively. Although the above modeling results provide one manner of achieving the selected threshold levels within the Oyster Pond system, the specific examples do not represent the only method for achieving this goal. However, the thresholds analysis provides general guidelines needed for the nitrogen management of this embayment

It is important to note that the analysis of future nitrogen loading to the Oyster Pond estuarine systems 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 Oyster Pond estuarine system is that restoration will necessitate a reduction in the present (2002) 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 Oyster Pond system, observed nitrogen concentrations, and sentinel system threshold nitrogen concentrations. Loads to estuarine waters of Oyster Pond include both upper watershed regions contributing to the major surface water inputs (Mosquito Creek).

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)
OYSTER POND SYSTEM										
Oyster Pond[a]	0.490	1.367	3.587	0.00	4.181	0.773	-1.733	3.220	0.67-0.71	--
Oyster Pond Lagoon	0.047	0.090	0.023	0.00	0.293	0.027	-0.048	0.273		--
Oyster Pond System Total	0.537	1.457	3.610	0.000	4.474	0.800	-1.781	3.493	0.67-0.71	**0.633**[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 1997 – 2004 data, ranges show the upper to lower regions (highest-lowest) of an sub-embayment.
[8] Threshold loading for Oyster Pond is based upon removal required to achieve 3.8, 5.0 or 6.0 mg/L DO concentration in the deepest basin of the Pond. Resulting TN concentrations in the lower Pond basin for these three scenarios are 0.633, 0.588 an d0.548 mg/L, respectively.
[a] Include loads from surface water sources (i.e., Mosquito Creek).

Table ES-2. Present Watershed Loads, Thresholds Loads, and the percent reductions necessary to achieve the Thresholds Loads for the Oyster Pond system, Town of Falmouth, Massachusetts. Threshold loading for Oyster Pond is based upon removal required to achieve 3.8, 5.0 or 6.0 mg/L DO concentration in the deepest basin of the Pond.

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
GREAT POND SYSTEM						
Oyster Pond	4.181	*DO 3.8*: 2.855 *DO 5.0*: 1.967 *DO 6.0*: 1.233	0.773	*DO 3.8*: -1.342 *DO 5.0*: -1.080 *DO 6.0*: -0.863	*DO 3.8*: 2.286 *DO 5.0*: 1.660 *DO 6.0*: 1.143	*DO 3.8*: -31.7% *DO 5.0*: -53.0% *DO 6.0*: -70.5%
Oyster Pond Lagoon	0.293	0.293	0.027	*DO 3.8*: -0.037 *DO 5.0*: -0.030 *DO 6.0*: -0.024	*DO 3.8*: 0.283 *DO 5.0*: 0.290 *DO 6.0*: 0.296	*DO 3.8*: 0.0 *DO 5.0*: 0.0 *DO 6.0*: 0.0
Oyster Pond System Total	4.474	*DO 3.8*: 3.148 *DO 5.0*: 2.260 *DO 6.0*: 1.526	0.800	*DO 3.8*: -1.379 *DO 5.0*: -1.110 *DO 6.0*: -0.887	*DO 3.8*: 2.569 *DO 5.0*: 1.950 *DO 6.0*: 1.439	*DO 3.8*: -29.6% *DO 5.0*: -49.5% *DO 6.0*: -65.9%

(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.