VIII. CRITICAL NUTRIENT THRESHOLD DETERMINATION AND DEVELOPMENT OF WATER QUALITY TARGETS

VIII.1. ASSESSMENT OF NITROGEN RELATED HABITAT QUALITY

Determination of site-specific nitrogen thresholds for an embayment requires integration of key habitat parameters (infauna and eelgrass), sediment characteristics, and nutrient related water quality information (particularly dissolved oxygen and chlorophyll-a). Additional information on temporal changes within each sub-embayment and its associated watershed nitrogen load further strengthens the analysis. These data were collected by the MEP Team to support threshold development for the Phinneys Harbor System and are discussed in Chapter VII. Nitrogen threshold development builds on this data and links habitat quality to summer water column nitrogen levels from the baseline BayWatcher Water Quality Monitoring Program, conducted by the Coalition for Buzzards Bay with technical support from the Coastal Systems Program at SMAST.

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. 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 (Table VIII-1).

Unlike many estuaries where the greatest nitrogen loading and impairment is in the inner basins, in the Phinneys Harbor System, most of the nitrogen loading is focused on the outer basin of Phinneys Harbor, as is the impairment. It is the outer basin which is capable of supporting eelgrass and which presently contains no eelgrass habitat. In contrast, the inner 2 basins are either naturally nutrient and organic matter enriched (Back River salt marsh) or are depositional basins not supportive of eelgrass, yet supportive of infaunal habitat (which was found to be relatively healthy). The result is a system with relatively healthy inner basins (based upon infaunal habitat) and an impaired outer basin (based on eelgrass loss).

Eelgrass: 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. Based upon eelgrass distributions in 1951 and 1985, eelgrass habitat is primarily within the shallower water depths (<2 m) along the northern shore (Mashnee Island) and southeastern basin of the Harbor. The 1985 data indicates that eelgrass habitat was relatively stable from 1951 to 1985. Within the 1951-1985 time-frame, eelgrass appears to have colonized most of the basin to depths of ~2 meters. It appears that the bathymetry of Phinneys Harbor limits the proportion of the basin that can support eelgrass, with much of the basin >3 meters in depth.

Table VIII-1. Summary of Nutrient Related Habitat Health within the Phinneys Harbor Estuary on the eastern coast of Buzzards Bay within the Town of Bourne, MA., based upon assessment data presented in Chapter VII. The estuarine reach of the Back River is presently a tidal salt marsh receiving freshwater discharge from the upper Back River. Eel Pond is a drowned kettle pond and Phinneys Harbor forms the lower estuary, which was formed in the 1930's by the construction of causeways to Mashnee Island to the north and Tobys Island to the south.

Health Indicator	Phinneys Harbor Estuarine System		
	Back River (salt marsh)	**Eel Pond**	**Phinneys Harbor**
Dissolved Oxygen	H[1]	MI[2]/H[3]	H[3]
Chlorophyll	H[4]	MI[5]	MI/H[3]
Macroalgae	--[6]	--[6]	--[6]
Eelgrass	--[9]	--[9]	MI/SI
Infaunal Animals	H	H/MI	H
Overall:	**H**	**H/MI**	**MI**

H = Healthy;
SD = Severe Degradation; -- = not applicable to this estuarine reach
MI = Moderately Impaired;
SI = Severely Impaired;

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. However, it is likely that if nitrogen loading were to decrease, eelgrass could first be restored in the lower portion of the main basin. With further reductions it may be possible for beds to be restored to the historic pattern, assuming other factors are not at play relative to eelgrass bed loss in Phinneys Harbor. Eelgrass recovery following nitrogen management would likely follow the pattern of beds first being re-established in the marginal areas in the outer region of Phinneys Harbor and then move to the inner regions. Note that restoration of this habitat will necessarily result in lower nitrogen levels in Eel Pond, as well (see Chapter VIII). Based upon the above analysis, eelgrass habitat should be the primary nitrogen management goal for the Phinneys Harbor System and is the focus of the management alternatives analysis (Chapter IX).

Water Quality: 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. Nitrogen enrichment of embayment waters generally manifests itself in the dissolved oxygen record, both through oxygen depletion and through the magnitude of the daily excursion. The high degree of temporal variation in bottom water dissolved oxygen concentration at each mooring site, underscores the need for continuous monitoring within these systems.

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. There was clear daily and tidal variation in dissolved oxygen and chlorophyll levels. 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).

Similarly, Back River presently shows greater oxygen depletions (to 3 mg/L), but lower chlorophyll a levels than Eel Pond (average 5.5 ug/L, general range 4-8 ug/L). This is consistent with it functioning primarily as a tidal salt marsh sub-basin. The low chlorophyll a levels result from its near complete exchange of tidal waters on each tide (compared to the deep basin of Eel Pond), which prevents a significant "build-up" of phytoplankton biomass. The low oxygen levels are also consistent with a salt marsh tidal creek, where the organic matter enriched sediments support high levels of oxygen uptake at night and deplete the overlying waters. While oxygen depletion to 3 mg/L would indicate impairment in an embayment like Phinneys Harbor basin, it is consistent with the organically enriched nature of smaller salt marsh creeks.

Infaunal Communities: The infaunal study indicated an overall system supporting generally healthy infaunal habitat relative to the ecosystem types represented. 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 infaunal habitat quality considered the natural structure of each system relative to the type of infaunal communities that they support.

The Phinneys Harbor basin has a range of depths and sediment types, with the central basin (>4 m) primarily composed of fine grained sands and muds. Marginal areas (<1.5 m) of the Harbor are composed of primarily sands and, particularly to the southeast, also gravel and rocks. 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. Back River is a tidal salt marsh system and as such supports infaunal communities tolerant of the organic enriched sediments typical of salt marshes. Salt marsh sediments are naturally enriched by organic matter as a result of their high productivity and the deposition in the tidal creeks of detritus originating on the emergent vegetated marsh plain. Additional organic matter enrichment results from the generally high nitrogen levels within the creeks which also support benthic production by microphytes. Salt marsh creeks generally have significant grazing pressure by fish. 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. Given the relatively deep nature of the kettle (2-3 m) and narrow outlet channel, the sediments of Eel Pond are composed of organically enriched mud. However, 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. In other small enclosed basins investigated by MEP, amphipods or capitellids have frequently been overwhelmingly dominant and indicate a moderately to significantly impaired habitat. This is not the case for Eel Pond. In fact, 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.

VIII.2. THRESHOLD NITROGEN CONCENTRATIONS

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.

Determination of the critical nitrogen threshold for maintaining high quality habitat within Phinneys Harbor Estuarine System is based primarily upon the nutrient and oxygen levels, temporal trends in eelgrass distribution and current benthic community indicators. Given the database, it is possible to develop a site-specific threshold, which is a refinement upon general threshold analysis frequently employed.

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 water quality monitoring data, there is a gradient in nitrogen within the outer basin, with the southeastern region showing slightly higher total nitrogen levels than the northern region or near the inlet. Tidally averaged total nitrogen (TN) levels in the southeastern region (station PH-4) were 0.369 mg N/L compared to 0.343-0.351 mg N/L for the other stations (PH 2,3,6). Station PH-5 within the outflow from the Back River was higher reflecting the nitrogen levels in the ebbing water from the upper 2 basins. 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.

Although the nitrogen management target is restoration of eelgrass habitat (and associated water clarity, shellfish and fisheries resources), benthic infaunal habitat quality must also be supported as a secondary condition. At present, the inner basins of Back River and Eel Pond appear to be relatively healthy and supportive of infaunal habitat. Given their structure and the historic absence of eelgrass in these systems, the MEP Technical Team selected infaunal habitat quality as the primary management target for these systems. The total nitrogen levels in these 2 upper basins for management are based upon the Back River Station EP-3 and the average Eel Pond watercolumn TN levels (average of EP-1 and EP-2).

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 secondary nitrogen threshold to ensure healthy infaunal habitat is set at <0.45 mg N/L based upon current conditions, 0.46 mg N/L where a slight level of impairment is indicated based upon the indicator species present (capitellids and spionids). The MEP has found a variety of nitrogen levels to be supportive of infaunal habitat based upon the basin type. Shallow vertically well-mixed basins tend to allow higher TN levels (e.g. Popponesset Bay, Three Bays at <0.5 mg N/L) and deeper basins, like Eel Pond, lower levels. However, the analysis of total nitrogen levels for Eel Pond with removal of all anthropogenic nitrogen loading from the entire System watershed still projects a tidally averaged level of 0.35 mg N/L. (which would not support eelgrass due to basin depth). However, the present high quality of Eel Pond infaunal habitat supports only the need for a small TN reduction and is consistent with the selected infaunal TN threshold. Note that when the TN threshold to support eelgrass habitat in the Phinneys Harbor basin is achieved, nitrogen levels within Eel Pond will also be lower than at present, a significant change relative to the secondary 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. The secondary criteria 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". The nitrogen loads associated with the threshold concentration at the sentinel location are discussed in Section VIII.3, below.

VIII.3. DEVELOPMENT OF TARGET NITROGEN LOADS

The nitrogen thresholds developed in the previous section were used to determine the amount of total nitrogen mass loading reduction required for restoration of eelgrass and infaunal habitats in the Phinney's Harbor estuary 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 stations chosen for Phinney's Harbor. 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 below represent only one of a suite of potential reduction approaches that need to be evaluated by the community. The presentation is to establish the general degree and spatial pattern of reduction that will be required for restoration of this nitrogen impaired embayment.

As shown in Table VIII-2, the nitrogen load reductions within the system necessary to achieve the threshold nitrogen concentrations required 80% removal of septic load (associated with direct groundwater discharge to the embayment) for the Phinney's Harbor and Phinney's Harbor Islands watersheds. The distribution of tidally-averaged nitrogen concentrations associated with the above thresholds analysis is shown in Figure VIII-1.

Table VIII-2. Comparison of sub-embayment watershed ***septic loads*** (attenuated) used for modeling of present and threshold loading scenarios of the Phinney's Harbor and Back River system. These loads do not include direct atmospheric deposition (onto the sub-embayment surface), benthic flux, runoff, or fertilizer loading terms.

sub-embayment	present septic load (kg/day)	threshold septic load (kg/day)	threshold septic load % change
Back River Inner	3.805	3.805	+0.0%
Back River Outer	1.381	1.381	+0.0%
Eel Pond	4.244	4.244	+0.0%
Phinney's Harbor	12.608	2.522	-80.0%

Tables VIII-3 and VIII-4 provide additional loading information associated with the thresholds analysis. Table VIII-3 shows the change to the total watershed loads, based upon the removal of septic loads depicted in Table VIII-2. Removal of 80% of the septic load from the Phinney's Harbor and Phinney's Harbor Islands watersheds results in a 68% reduction in total nitrogen load. Table VIII-4 shows the breakdown of threshold sub-embayment and surface water loads used for total nitrogen modeling. In Table VIII-4, loading rates are shown in kilograms per day, since benthic loading varies throughout the year and the values shown represent 'worst-case' summertime conditions. The benthic flux for this modeling effort is reduced from existing conditions based on the load reduction and the observed particulate organic nitrogen (PON) concentrations within each sub-embayment relative to background concentrations in Buzzards Bay.

Table VIII-3. Comparison of sub-embayment ***total attenuated watershed loads*** (including septic, runoff, and fertilizer) used for modeling of present and threshold loading scenarios of the Phinney's Harbor and Back River system. These loads do not include direct atmospheric deposition (onto the sub-embayment surface) or benthic flux loading terms.

sub-embayment	present load (kg/day)	threshold load (kg/day)	threshold % change
Back River Inner	7.699	7.699	+0.0%
Back River Outer	1.964	1.964	+0.0%
Eel Pond	4.888	4.888	+0.0%
Phinney's Harbor	14.781	4.694	-68.2%

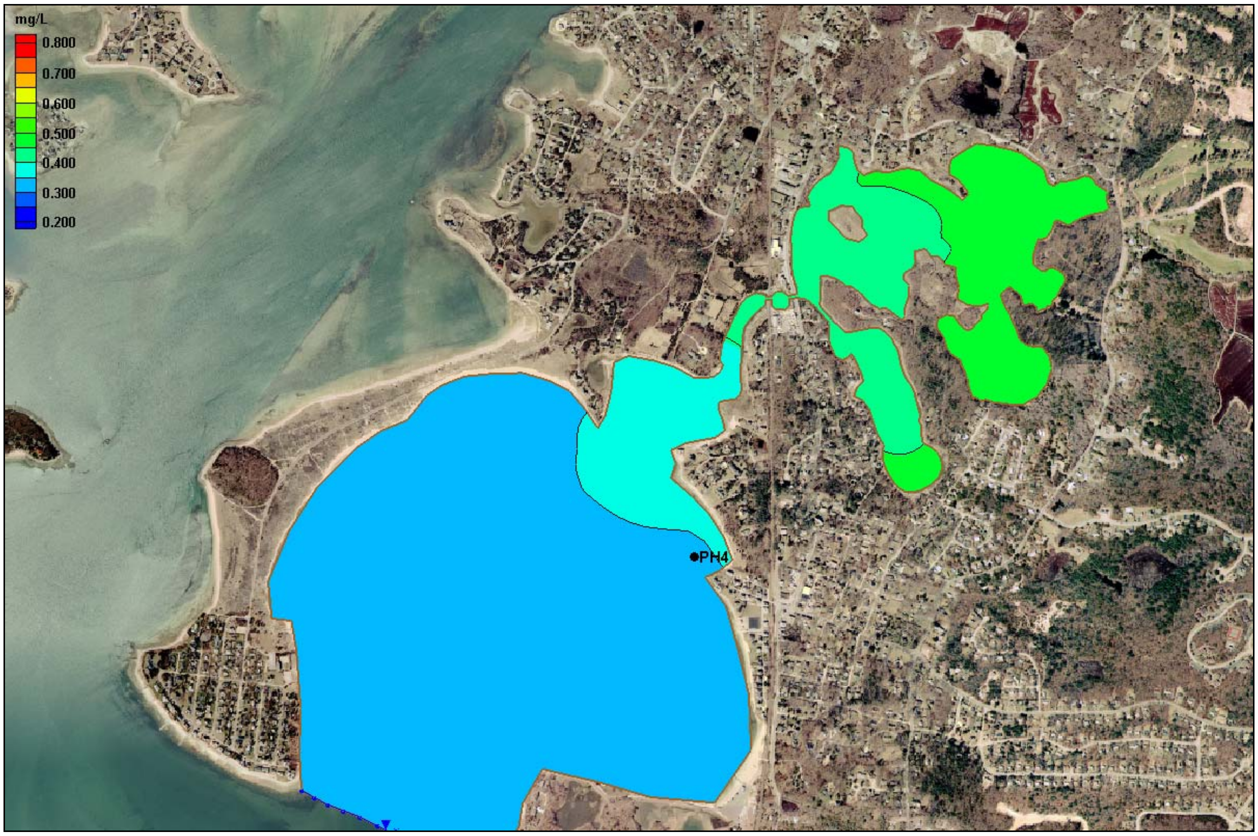

Figure VIII-1. Contour plot of modeled average total nitrogen concentrations (mg/L) in the Phinney's Harbor estuary system, for threshold conditions (0.35 mg/L at water quality monitoring.

Table VIII-4. Threshold sub-embayment loads and attenuated surface water loads used for total nitrogen modeling of the Phinney's Harbor and Back River system, with total watershed N loads, atmospheric N loads, and benthic flux

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)
Back River Inner	7.699	0.589	0.976
Back River Outer	1.964	0.340	0.562
Eel Pond	4.888	0.246	-0.709
Phinney's Harbor	4.694	5.186	12.165

Comparison of model results between existing loading conditions and the selected loading scenario to achieve the target TN concentrations at the sentinel station is shown in Table VIII-5. To achieve the threshold nitrogen concentrations at the sentinel station, a reduction in TN concentration of approximately 5% is required at Phinney's Harbor station PH4. The reduction in septic load to Phinney's Harbor results in a reduction in TN concentration of approximately 3% across the entire system.

The basis for the watershed nitrogen removal strategy utilized to achieve the embayment thresholds may have merit, since this example nitrogen remediation effort is focused on watersheds where groundwater is flowing directly into the estuary. For nutrient loads entering the systems through surface flow, natural attenuation in freshwater bodies (i.e., streams and ponds) can significantly reduce the load that finally reaches the estuary. Presently, this attenuation is occurring due to natural ecosystem processes and the extent of attenuation being determined by the mass of nitrogen which discharges to these systems. The nitrogen reaching these systems is currently “unplanned”, resulting primarily from the widely distributed non-point nitrogen sources (e.g. septic systems, lawns, etc.). Future nitrogen management should take advantage of natural nitrogen attenuation, where possible, to ensure the most cost-effective nitrogen reduction strategies. However, “planned” use of natural systems has to be done carefully and with the full analysis to ensure that degradation of these systems will not occur. One clear finding of the MEP has been the need for analysis of the potential associated with restored wetlands or ecologically engineered ponds/wetlands to enhance nitrogen attenuation. Attenuation by ponds in agricultural systems has also been found to work in some cranberry bog systems, as well. Cranberry bogs, other freshwater wetland resources, and freshwater ponds provide opportunities for enhancing natural attenuation of their nitrogen loads. Restoration or enhancement of wetlands and ponds associated with the lower ends of rivers and/or streams discharging to estuaries are seen as providing a dual service of lowering infrastructure costs associated with wastewater management and increasing aquatic resources associated within the watershed and upper estuarine reaches.

Table VIII-5. Comparison of model average total N concentrations from present loading and the modeled threshold scenario, with percent change, for the Phinney’s Harbor and Back River system. Sentinel threshold station are in bold print.

Sub-Embayment	monitoring station	present (mg/L)	threshold (mg/L)	% change
Phinney’s Harbor	PH2	0.347	0.335	-3.5%
Phinney’s Harbor	PH3	0.351	0.339	-3.6%
Phinney’s Harbor	**PH4**	**0.369**	**0.352**	**-4.6%**
Phinney’s Harbor	PH5	0.390	0.377	-3.5%
Phinney’s Harbor	PH6	0.343	0.334	-2.6%
Eel Pond - Inner	EP1	0.470	0.456	-3.1%
Eel Pond - Middle	EP2	0.437	0.423	-3.3%
Eel Pond – Back River	EP3	0.423	0.408	-3.4%

Although the above modeling results provide one manner of achieving the selected threshold level for the sentinel site within the estuarine system, the specific example does not represent the only method for achieving this goal. However, the thresholds analysis provides general guidelines needed for the nitrogen management of this embayment.

VIII.4. EELGRASS NITROGEN THRESHOLD FOR PHINNEYS HARBOR

It has been documented that Phinneys Harbor supported eelgrass along Mashnee Neck and along Monument Beach prior to the 1995 DEP survey. This eelgrass habitat was confined to the shallower waters. There was no evidence of eelgrass in the Back River inlet or in the ebb tidal "plume" region, consistent with the nitrogen level in the Back River of 0.390 mg N/L. The selected sentinel station (PH4) currently has a tidally averaged nitrogen level of 0.37 mg N/L and a measured level of 0.375 mgN/L. The locations targeted for eelgrass restoration and hence this threshold target are in the inner shallow margins of the Phinneys Harbor main basin along Mashnee Neck and Monument Beach. The Mashnee Neck area was observed to have eelgrass in 1951 (map by DEP) and Mashnee Neck and Monument Beach areas had eelgrass in a 1980's survey (Costa).

The nitrogen threshold for Phinneys Harbor was based in part upon the fact that in Phinneys Harbor, nitrogen levels of 0.37-0.39 mgN/L were not supportive of eelgrass. In addition, the eelgrass threshold for nearby West Falmouth Harbor where a strong data base of nitrogen sampling and eelgrass mapping existed, was clearly 0.35 mgN/L. In the West Falmouth Harbor System, observed nitrogen concentrations in the region of the junction of the outer and mid-inner harbor documented that eelgrass loss was occurring at 0.37 mgN/L tidally averaged watercolumn concentration. This site is particularly well suited for evaluation of historic eelgrass loss, as it had a nearby monitoring station and also had mapping (1999) which revealed the thinning of the beds (to 15%-20% cover) and more recent mapping indicating a disappearance of the beds. Since Phinneys Harbor and West Falmouth Harbor systems are generally similar in configuration, source water, tide range and depth (both even have tributary salt marsh inflows), a consistent threshold would be expected.

The eelgrass in Nantucket Harbor in similar physical locations to Phinneys Harbor clearly shows stable eelgrass beds at tidally averaged nitrogen levels of 0.34 mgN/L, but not at 0.36 mgN/L or 0.37 mgN/L. In fact there has been a long-standing issue with the presence of stable beds at the lower reach of the Head of the Harbor basin, and the absence of beds throughout the rest of that basin, even along the shallow margins. This has been attributed to nitrogen levels and is consistent with the nitrogen gradient observed both in the water quality monitoring data and the modeled results.

All of these relatively similar systems show eelgrass and watercolumn nitrogen distributions consistent with a loss of eelgrass at nitrogen levels higher than 0.35 mgN/L and an absence of eelgrass at levels of 0.37 mgN/L. However, this well-defined threshold nitrogen concentration for restoration of eelgrass habitat in these systems should not be construed as a general threshold level of other systems.

Eelgrass Loss Other Factors:

While there can be a variety of factors which influence eelgrass distribution, they do not occur in all basins. In the case of Phinneys Harbor, eelgrass was lost in non-mooring areas and at depths not typical of powerboat scarring (prop disturbance). Further, the evidence does not support dredging impacts or release of toxic contaminants, like oil spills or release of herbicides. Therefore based upon the positive evidence of the nitrogen and eelgrass distribution data and the negative evidence of the lack of "other" factors, supports the conclusion that nitrogen inputs are the key to managing this system. It should be noted that in the region of station PH3, eelgrass loss may have been locally enhanced by the presence of a boat mooring area, but this does not apply to the much greater areas where loss has occurred.

Related Key Points:

(a) The concept of a nitrogen threshold to support eelgrass habitat is that it is the nitrogen level beyond which eelgrass will not be supported. The sharpness of the threshold is likely related to water depth, with deeper basins being less tolerant of nitrogen loading. Phinneys Harbor contains a relatively deep central region, which did not support eelgrass in either the 1951 or the 1980's (according to historic eelgrass survey data).

(b) The present tidally averaged nitrogen level in Inner Phinneys Harbor at the sentinel station is presently 0.37 mgN/L. The threshold level for eelgrass restoration is 0.35 mgN/L. Since the background watercolumn nitrogen level is 0.30 mgN/L, the difference in present nitrogen level results from the enrichment of the tidal waters during their residence within the basin, due to watershed and atmospheric nitrogen loading. The difference in the nitrogen level increase over background Buzzards Bay waters of 0.05 mg/L (at threshold) and 0.07 mgN/L (present) represents a 40% increase and will require a similar order of magnitude decrease in watershed N loading to lower levels to the threshold target. The septic system alternative evaluated (only one of many potential nitrogen reduction scenarios) indicated that a ~45% decrease in watershed N load would be needed to achieve the 0.35 mgN/L threshold. The overall amount of nitrogen reduction is relatively modest (~10 kg N/watershed/day out of >29 kg N/watershed/day total load). This is relatively moderate nitrogen reduction to meet the threshold nitrogen concentration target is to be expected, since the system supported eelgrass in the 1980's and has a moderate overall N loading compared to nearby West Falmouth Harbor (>42 kg N/watershed/day).