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 watershed further strengthen the analysis. These data were collected to support threshold development for the Rushy Marsh Pond System by MEP Team and were discussed in Chapter VII. Nitrogen threshold development builds on this data and links habitat quality to summer water column nitrogen levels from the long-term baseline Water Quality Monitoring Program conducted by Three Bays Preservation in partnership with the Town of Barnstable, with technical guidance from the Coastal Systems Program at SMAST. At present, Rushy Marsh Pond is showing significantly impaired to severely degraded habitat quality. All of the habitat indicators are consistent with this evaluation of the whole of system (Chapter VII).

Eelgrass: At present, eelgrass is not found within Rushy Marsh Pond. The current lack of eelgrass beds is expected given the high chlorophyll a and low dissolved oxygen levels and watercolumn nitrogen concentrations within this system. In addition, it does not appear that eelgrass beds were present in the system in 1951. It appears that the restriction of the tidal exchange starting circa 1900, resulted in an absence of eelgrass sometime prior to 1951. The restriction of tidal exchange has resulted in an enrichment of estuarine waters in nitrogen to the extent that the system is currently eutrophic. Restoration of tidal exchange will be needed for habitat restoration of this system, as watershed nitrogen inputs are relatively low.

Given that eelgrass has not been documented for this system, it is not clear that even when the system was much better flushed, it supported eelgrass beds. However, observations of brackish water submerged aquatic vegetation in the shallow region of the western channel suggest that eelgrass habitat might be sustainable under lower effective nitrogen loading rates (i.e. higher flushing). To the extent that conditions could be improved to the level of eelgrass colonization in this system, the acreage would likely range from 4-12 acres, most likely in the southern channel and the margins of the main basin.

The eelgrass information is consistent with the results of the benthic infauna analysis and the observed eelgrass loss is typical of nutrient enriched shallow embayments (see below).

Water Quality: Rushy Marsh Pond currently exhibits seasonal oxygen stress, consistent with nitrogen enrichment (Tables VII-1, VII-2). That the cause is eutrophication is supported by the high levels of chlorophyll a, 15 ug/L to >20 ug/L (Table VII-2). Oxygen conditions and chlorophyll a levels indicated nutrient related stress throughout the Pond

The level of oxygen depletion and the magnitude of daily oxygen excursion and chlorophyll a levels indicate highly nutrient enriched waters and impaired habitat quality within the estuary (Figures VII-3, VII-4). Oxygen depletion was frequently to levels <4 mg/L (29 days) and periodically to < 3 mg/L (8 days). The oxygen data is consistent with high organic matter loads from phytoplankton production (chlorophyll a levels) indicative of nitrogen enrichment and eutrophication of this estuarine system, although the nitrogen enrichment stems primarily from the restriction of tidal exchange. The frequent significant level of oxygen depletion coupled to the frequent phytoplankton blooms is clear evidence of that Rushy Marsh Pond is presently nitrogen over-loaded eutrophic embayment. The chlorophyll a, dissolved oxygen and total nitrogen within Rushy Marsh Pond are consistent with the observed eelgrass losses (above) and the significantly impaired infaunal animal communities (below).

Infaunal Communities: The Infauna Study indicated that all areas are presently severely degraded and that habitat capable of sustaining benthic infaunal animals is virtually absent in Rushy Marsh Pond (Table VII-3). The infaunal survey found that summer conditions apparently are sufficient to prevent a community from developing in the central basin. In the shallower southern channel region, again only very few individuals and species were found. The low numbers of species and individuals indicates that benthic infaunal habitat has been severely degraded throughout Rushy Marsh Pond. The conditions proximately result from the high level of nitrogen and organic matter enrichment and associated oxygen depletion of bottom waters. Ultimately, the cause is the highly restricted tidal exchange and very low flushing rate of Pond waters (system residence time ~48 d). However, restoration of infaunal animal communities should occur at the point that habitat can be restored.

The infaunal community based classification throughout Rushy Marsh Pond is fully supported by the water quality and eelgrass data discussed in the text above.

Table VIII-1. Summary of Nutrient Related Habitat Health within the Rushy Marsh Pond Estuary on the south shore of Barnstable, MA., based upon assessment data presented in Chapter VII.

Health Indicator	Estuary Rushy Marsh Main Basin	Estuary Rushy Marsh Channel
Dissolved Oxygen	SI/SD[1]	--
Chlorophyll	SI	SI
Macroalgae	SI/SD[2]	SI
Eelgrass	SI/SD[3]	SI[4]
Infaunal Animals	SD[5]	SD
Overall:	**SD**	**SD**

1 – periodic oxygen depletions to <3 mg/L and frequently <4 mg/L.
2 – macroalgal accumulations on bottom.
3 – no eelgrass in pond presently and likely for over 60 years.
4 – no eelgrass, but strands of brackish submerged aquatic vegetation, possibly *Ruppia*.
5 – virtual absence of infaunal animal community in 2004 survey.
H = healthy habitat conditions; MI = Moderate Impairment; SI = Significant Impairment; SD = Severe Degradation
-- = not applicable to this estuarine reach

VIII.2 THRESHOLD NITROGEN CONCENTRATIONS

The approach for determining nitrogen loading rates, which will maintain acceptable habitat quality throughout and 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.

Within the Rushy Marsh Estuary the most appropriate sentinel station was about in the center of the basin at Station RM2 in Figure VIII-1. This location was selected because restoration of nitrogen conditions supportive of eelgrass or infauna at this location will necessarily result in similar quality conditions throughout the basin. As is shown below and in Chapter IX, concentrations at the Sentinel Station (RM2) approximate concentrations throughout the pond waters (i.e. it is representative or higher than the other pond locations).

Following the MEP protocol, since eelgrass has not been documented in Rushy Marsh Pond, restoration of infaunal habitat is the restoration goal. Infaunal animal habitat is a critical resource to the Rushy Marsh System and estuaries in general. Since there are virtually no infaunal animals remaining in the sub-tidal Rushy Marsh Pond sediments, comparisons to the muddy basins of other nearby estuarine systems were relied upon for setting the nitrogen threshold for healthy infaunal habitat at a nitrogen level of TN <0.5 mg TN L^{-1}. This level was found for Popponesset Bay where based upon the infaunal analysis coupled with the nitrogen data (measured and modeled), nitrogen levels on the order of 0.4 to 0.5 mg TN L-1 were found supportive of high infaunal habitat quality in this system. Similarly, in the Three Bays System, healthy infaunal areas are found at nitrogen levels of TN <0.42 mg TN L^{-1} (Cotuit Bay and West Bay), with impairment in areas where nitrogen levels of TN >0.5 mg TN L^{-1} (North Bay), and severe degradation at nitrogen levels of TN >0.6 mg TN L^{-1}.

Given the low watershed nitrogen load to Rushy Marsh Pond, reconstruction of the tidal inlet will be required to meet the nitrogen threshold level and achieve restoration of this system. In addition, restoration of tidal exchange (i.e. tide range) will allow the restoration of fringing salt marsh in this system, which has lost its salt water wetlands.

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 Rushy Marsh. 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 Rushy Marsh. 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 were not attainable with 100% removal of septic load (associated with direct groundwater discharge to the embayment) for the systems watershed. The limited circulation within the system prevents the threshold goals from be achieved. In order to meet the threshold concentrations in the system, alternative approaches beyond load reductions are required to increase circulation and water exchange with Nantucket Sound. 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 Rushy Marsh 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
Rushy Marsh	0.353	0.000	-100.0%

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 100% of the septic load from the watershed of Rushy Marsh results in an 79% reduction in total nitrogen load. Table VIII-4 shows the breakdown of threshold sub-embayment 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 Nantucket Sound.

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 Rushy Marsh 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
Rushy Marsh	0.447	0.093	-79.1%

Table VIII-4. Threshold sub-embayment loads and attenuated surface water loads used for total nitrogen modeling of the Rushy Marsh 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)
Rushy Marsh	0.093	0.203	-0.113

Comparison of model results between existing loading conditions and the selected loading scenario attempting 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 different structural approach to increase circulation in the system is required for Rushy Marsh.

Table VIII-5. Comparison of model average total N concentrations from present loading and the modeled potential threshold scenario, with percent change, for the Rushy Marsh system. This threshold scenario (100% of septic, Table VIII-2) failed to meet the infaunal threshold (<0.5 mg N/L) at the sentinel station (bold print)

Sub-Embayment	monitoring station	present (mg/L)	threshold (mg/L)	% change
Rushy Marsh - north	RM1	1.102	0.988	-10.4%
Rushy Marsh - east	**RM2**	**1.107**	**0.990**	**-10.6%**
Rushy Marsh - west	RM3	1.108	0.991	-10.6%
Rushy Marsh - south	RM4	1.156	1.018	-11.9%