II. PREVIOUS STUDIES RELATED TO NITROGEN MANAGEMENT

In most marine and estuarine systems, such as the Slocums River and Little River embayments the limiting nutrient, and thus the nutrient of primary concern, is nitrogen. In large part, if nitrogen addition is managed, then eutrophication is controlled. This approach has been formalized through the development of tools for predicting nitrogen loads from watersheds and the concentrations of water column nitrogen that may result. Additional development of the eutrophication management approaches via the reduction of nitrogen loads has also generated specific guidelines as to what is to be considered acceptable water column nitrogen concentrations to achieve desired water quality goals (e.g., see Cape Cod Commission 1991, 1998; Howes et al. 2003).

Until recently, these tools for predicting loads and concentrations tended to be generic in nature, and overlooked some of the site-specific characteristics associated with a given water body. The present Massachusetts Estuaries Project (MEP) study focuses on linking water quality model predictions, based upon watershed nitrogen loading and embayment recycling and system hydrodynamics, to actual measured values for specific nutrient species. The linked watershed-embayment model is built using embayment specific measurements, thus enabling calibration of the prediction process for specific conditions in each of the coastal embayments of southeastern Massachusetts, including the Slocums River and Little River systems.

Beginning in 1990, nutrient loading evaluations for all Dartmouth embayments were included in the initial and then subsequently updated nitrogen loading and management strategy plans for all Buzzards Bay embayments (Buzzards Bay Comprehensive Conservation and Management Plan (CCMP) issued by the Buzzards Bay National Estuary Program (BBNEP 1991). The 1991 CCMP used embayment–specific hydrodynamic data and available land-use data to characterize the Total Maximum Annual Nitrogen Load (TMAL) for a given embayment. The 1991 tiered nitrogen loading model assigned values for nitrogen generation and transport within a watershed using: watershed delineations; land usage characterizations (e.g., forest, water, cropland and pasture, commercial, residential, industrial, marsh, transportation, etc.); their respective land-use area measurements using GIS (Geographical Information Systems); and the hydrodynamic characteristics of the embayment (bathymetry, volume, estuary turn-over time) to calculate the nitrogen loading to each embayment. The TMAL was a measure of each embayments ability to meet one of several regulatory water quality classifications. For the Slocums River, a classification of SA, the second highest marine waters classification, has been set by MA Department of Environmental Protection, while Little River has been classified as the highest level, an Outstanding Resource Water (ORW). The 1991 CCMP loading model calculated a recommended load limit of 29,600 kg of nitrogen per year while the calculated 1991 existing nitrogen load to the Slocums River at was 97,000 kg nitrogen per year, or more than three times the recommended limit.

The CCMP Nitrogen loading model data was used as a starting point for the nitrogen management portion of the CCMP. The Buzzards Bay Action Plan outlined measures that Town could adopt to manage nitrogen inputs to the regions embayments. The recommendations the Action Plan provided to municipalities included conducting parcel by parcel build-out analysis of the watersheds; sewering when appropriate; adoption of nitrogen–loading bylaws for sensitive embayments; reduction of agricultural fertilizer use by cranberry growers (there are two bogs in the Slocums River watershed); and the implementation of agricultural best-management practices for fertilizers and manure.

Since the late 1980's the Town of Dartmouth has instituted many of the recommendations of the CCMP in order to improve ground and surface water quality in the Town. Many of these measures resulted in some reduction in nitrogen transport to the embayments. The Planning Board adopted stormwater regulations that required constructed wetlands and other stormwater management tools to treat parking lot and roof runoff for new commercial and residential projects. When older commercial developments are remodeled or increased in scale, the Planning Board negotiates improvements in stormwater management infrastructure that tend to improve stream water quality. The Town has adopted several Aquifer Protection Zones that limit the intensity and type of development which can occur within the protection zones and the rules indirectly limit the increase in nitrogen in the Slocums River watershed. The Board of Health provides oversight and collaboration on best management practices for manure, fertilizer and composting with farmers to lessen runoff of contaminants to town streams. The Department of Public Works has worked to improve stormwater runoff by installing several stormwater treatment units and has recently purchased storm drain maintenance equipment to improve the performance of the existing infrastructure. The Department of Public Works has extended the sewer network along Route 6 and northward along Reed Road, thereby reducing the nitrogen load in the Westport River watershed. Additionally, planning is underway for an extension of sewer lines to serve the Bay View neighborhood on Smith Neck Road, and when completed will reduce the nitrogen inputs to Outer Apponagansett Bay. Since the mid-1980's the Town has increased protected open space through land purchases and conservation easements for substantial parcels of land throughout the Town, thereby substantially limiting the amount of future buildout-related nitrogen. It is likely that these combined efforts have and will continue to contribute to a slowing in the rate of increase of nitrogen loading to the Town embayments.

Beginning in 1993, summer measurement of nutrient levels (dissolved and particulate nitrogen; phosphorus); and other water quality indicators, (chlorophyll; secchi depth, dissolved oxygen and temperature) was begun in the Slocums and Little River embayments by the Baywatchers program instituted by the Coalition for Buzzards Bay for most Buzzards Bay estuaries. The Coalition's BayWatcher Program has collected the principal baseline water quality data necessary for ecological management of each of Dartmouth's embayments and harbors. The BayWatcher is a citizen-based water quality monitoring program that is run by the Coalition for Buzzards Bay (T. Williams, Project Coordination) with technical and analytical assistance from the Coastal Systems Program at SMAST-UMD.

The common focus of the Coalition for Buzzards Bay BayWatcher Water Quality Monitoring Program effort has been to gather site-specific data on the current nitrogen related water quality throughout all the embayments tributary to Buzzards Bay. The program was tailored to the gathering of data specifically to support evaluations relating observed water quality to habitat health. The BayWatcher Water Quality Monitoring Program in the Slocums River Embayment System developed a data set that elucidated the long-term water quality of this system. The BayWatcher Program provided the quantitative watercolumn nitrogen data (1999-2006) required for the implementation of the MEP's Linked Watershed-Embayment Approach. The MEP effort also builds upon the previous watershed delineation and land-use analyses, river transport and attenuation data, and embayment water quality and eelgrass surveys. This information is integrated with MEP collected higher order biogeochemical analyses and water quality modeling necessary to develop critical nitrogen targets for the Slocums River System. The MEP has incorporated all appropriate data from all previous studies to enhance the determination of nitrogen thresholds for the Slocums River System and to reduce costs to the Town of Dartmouth.

In 1999 the first 7 years of embayment data from 30 embayments monitored by the Baywatchers Program was compared with the 1991 BBNEP Buzzards Bay nitrogen loading model results (Costa et al, 1999). The 1999 study undertook a comparative analysis of previous studies of nitrogen loading and ecosystem responses and compared those analyses with the BayWatchers results, using the BayWatchers data as a yardstick for CCMP model evaluation. Costa et al. found that the revised loading methodology yielded somewhat lower existing loading levels to the Slocums River at 93,541 kg of nitrogen per year and at the same time revising the TMAL limit downward from 29,600 kg of nitrogen annually to 12,000 kg of nitrogen per year. The 1999 change in nitrogen load recommendation underscores the seven-fold imbalance that exists between the Slocums River recommended nitrogen "carrying capacity" and the 1999 estimate of nitrogen load (Costa et al. 1999).

For Little River the BBNEP estimated existing nitrogen loading for 1999 was 51% of the recommended TMAL for that embayment, or 2,608 kg n/y of the 5,000 kg/y total nitrogen recommended threshold (BBNEP,1999)

After the first ten years of monitoring, the BayWatchers data set was reviewed in 2001 by the Coalition for Buzzards Bay and summarized in a report for the first period, 1992-2001 (CBB 2002). For Inner Slocums River the Baywatchers data indicated finding consistently poor/eutrophic water quality in seven of nine years of samples from Inner Slocums River; fair water quality in seven of 9 years of samples at Outer Slocums River with one season (1999) having good summer water quality. In Little River the 2002 report indicated that Inner Little River had poor/eutrophic water quality during five of the nine seasons sampled; Outer Little River had fair water quality during six of the nine seasons, with one season, 1999 showing good to excellent water quality (CBB 2003). More recent 5-year running averages of the health indexes for the Slocums River and Little River through the summer of 2005 show no improvement in the water quality of both Inner and Outer Slocums River and Outer Little River sites. The health index for Inner Little River showed some small improvement, with 5 of the past 6 years of data falling in the lowest range of fair to good water quality (CBB, 2006). In comparison to other Buzzards Bay embayments sampled by the BayWatchers program, the Slocums River and Little River "Health Index" ratings were consistently in the lowest third of all 29 embayments.

In addition to the BayWatcher's data, other data collected relative to nutrient levels in the Slocums River began in the mid-1960's with a two-year hydrographic study by Hoff et al. (1968). Hoff measured nitrate and phosphorus concentrations at four locations within the Slocums River and one station at Barneys Joy Point in Buzzards Bay and found a nitrate gradient between "extremely high levels" at the head of the Slocums River at Russells Mills and "very low levels" of nitrate at the mouth of the Slocums River. Hoff proposed that the nitrate gradient was likely due to the freshwater origin of the nitrogen inputs in the Upper Slocums River, tidal dilution with cleaner Buzzards Bay water and cyclical uptake by diatom species. Hoff did not measure the other species of nitrogen, ammonium, dissolved organic nitrogen and particulate nitrogen that when summed give a more complete picture of the nitrogen levels in the estuary. Thus, it is difficult to evaluate the level of total nitrogen in the estuary during the period using Hoff's data.

Between 1995 and 1997 nitrogen levels were measured in the Slocums River, Paskamanset River and Destruction Brook by the U.S. Environmental Protection Agency as part of a comparative study of anthropogenic impacts upon the Slocums River, the Westport River and New Bedford Harbor-Acushnet River (Johnson, et al, US EPA 2000). For the Paskamanset River and Destruction Brook watersheds combined, together representing about 86 % of the land watershed of the Slocums River, EPA calculated the average daily dissolved inorganic nitrogen (DIN) load (ammonium + nitrate + nitrite) at 44.45 kg DIN per day or 16,225 kg DIN

annually. The total nitrogen load for the streams is larger because DIN values are a variable fraction of the stream total nitrogen load and dissolved organic and particulate nitrogen are not included in the EPA measured DIN carried by those two streams. To estimate the total nitrogen using the EPA 1995-1997 data, we can use the average DIN and total nitrogen data from 346 samples collected between 2003 and 2005 at the mouths of the Paskamanset River and Destruction Brook for this study (we must assume that no substantial changes in stream nitrogen species fractions in these streams has occurred in the interim). After normalizing for the relative stream watershed area of the Paskamanset River and Destruction Brook, the average DIN fraction of total nitrogen in the samples is 0.39. When applied to the EPA average, estimated total nitrogen is about 114 kg TN per day or about 41,600 kg total nitrogen per year from the upper Slocums River watershed, or about one-half (44%) of the BBNEP estimated nitrogen load delivered from the upper 86% of the Slocums River watershed. Even so, this TN estimate based on the 1995 EPA DIN data indicates that the Slocums River TN input was about 3.5 times greater than the BBNEP loading threshold of 12,000 kg TN per year. The EPA nitrogen loading also exceeded that of two other nearby estuaries in 1995. Johnson (2000) normalized the DIN load to each of the three estuaries by factoring in the estuary volume and the estuary flushing time, an adjustment that reduces the effects of the physical differences between the estuaries. Using the normalized DIN values, Johnson concluded that compared to the West Branch of the Westport River and New Bedford Harbor, the Slocums River DIN loading was about two times greater than the other two estuaries.

Considering all the historical nitrogen loading data sets: 1) the BayWatchers nitrogen and other water quality indicator measurements, 2) the US EPA data from 1996, 3) the 1999 revised BBNEP embayment loading model current land use estimate, the Slocums River appears beyond its assimilative capacity for nitrogen. The data also indicates that the Slocums River probably was excessively loaded with nitrogen before 1991. Estimates of the overload vary between c.a. three times (US EPA data) to more than seven times the assimilative capacity as determined in the past by the BBNEP in 1999. The MEP is a refinement of all the above loading estimates factoring refinement of the watershed delineations, detailed land use analysis on a parcel by parcel basis (including water use data) and measured stream flow and nitrogen loading at all the surface water inflows to the overall Slocums River System.

In Little River the BBNEP estimated existing nitrogen loading for 1999 was 2,608 kg n/y, or 51% of the recommended TMAL for that embayment of 5,000 kg/y total nitrogen (BBNEP,1999). This level would appear to indicate that Little River is comfortably below the level at which eutrophication and habitat degradation will begin. However, the BayWatchers Little River monitoring data for the same time period indicated a disagreement between the BayWatchers' measured water quality, which has been generally poor to fair for Inner Little River and the 1999 BBNEP loading estimates which indicate otherwise. It seems likely given the monitoring data, that some other factors may be affecting the water quality in Little River. The MEP has generated a refined watershed and hydrodynamic analysis of the Little River system in order to clarify the historical discrepancy.