II. PREVIOUS STUDIES RELATED TO NITROGEN MANAGEMENT

Nutrient additions to aquatic systems cause shifts in a series of biological processes that can result in impaired nutrient related habitat quality. Effects include excessive plankton and macrophyte growth, which in turn lead to reduced water clarity, organic matter enrichment of waters and sediments with the concomitant increased rates of oxygen consumption and periodic depletion of dissolved oxygen, especially in bottom waters, and the limitation of the growth of desirable species such as eelgrass. Even without changes to water clarity and bottom water dissolved oxygen, the increased organic matter deposition to the sediments generally results in a decline in habitat quality for benthic infaunal communities (animals living in the sediments). This habitat change causes a shift in infaunal communities from high diversity deep burrowing forms (which include economically important species), to low diversity shallow dwelling organisms. This shift alone causes significant degradation of the resource and a loss of productivity to both the local shellfisherman and to the sport-fishery and offshore finfishery, which are dependant upon these highly productive estuarine systems as a habitat and food resource during migration or during different phases of their life cycles. This process is generally termed “eutrophication” and in embayment systems, unlike in shallow lakes and pond, it is not a necessarily a part of the natural evolution of a system.

In most marine and estuarine systems, such as the Centerville River System, the limiting nutrient, and thus the nutrient of primary concern, is nitrogen. In large part, if nitrogen addition is controlled, 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 approach 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. 2002).

These tools for predicting loads and concentrations tend to be generic in nature, and overlook some of the specifics for any 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 Centerville River System. As the MEP approach requires substantial amounts of site specific data collection, part of the program is to review previous data collection and modeling efforts. These reviews are both for purposes of “data mining” and to gather additional information on an estuary’s habitat quality or unique features.

A number of studies relating to nitrogen loading, hydrodynamics (mostly in the context of dredging) and habitat health have been conducted within the Centerville River System over the past 10 years. The most directly applicable study relative to the objectives of the MEP focused on nitrogen fluxes and mitigation strategies in the Audubon Skunknett River Wildlife Sanctuary (Hamersley, 2004). The study is significant relative to elucidating the potential for natural attenuation within the Centerville River watershed as well as being an independent confirmation of the MEP stream gaging effort on the Skunknett River. The study was undertaken by an SMAST-Coastal Systems Program scientist directly involved in researching biogeochemical aspects of nutrient cycling to the direct benefit of the MEP analytical approach utilized in this analysis of the Centerville River System. As described in the Skunknett River Wildlife

Sanctuary Report, increasing development in the watershed of Scudder Bay (tributary sub-embayment to Centerville River) has led to algal blooms and eutrophication of the estuarine receiving water. Two point sources for nutrients entering the bay are the Skunknett and Bumps Rivers. The Skunknett River flows through the Audubon Skunknett River Wildlife Sanctuary (ASRWS), the site of four former or existing ponds. The former ponds were created in the 19th century by dams which washed out in the early 1990's. Restoring these ponds has the potential to support the removal of nitrogen from the Skunknett River via the natural bioremediation processes of denitrification and storage. The removal by denitrification is primarily dependent on contact with organic-rich sediments. Restoring the ponds would increase the contact time of the sediments, as well as their organic content through deposition. Hydrological and nutrient fluxes into and out of the Sanctuary were measured in the summer of 2002 and through most of the year 2003 in order to perform a preliminary evaluation of the feasibility of restoring one or more of the ponds to enhance the removal of nitrogen from the Skunknett River.

The preliminary analysis of the Skunknett River aquatic system (inclusive of the associated pond system) suggested that the Skunknett River represents a significant source of nitrogen to Scudder Bay, and that much of this nitrogen is in the form of nitrate, making it amenable to removal through denitrification. As measured at the time of the study (2002-2003) the Skunknett River generated a total nitrogen load to Scudder Bay of 8,490 kg N/yr. Housing development in the Skunknett River watershed will likely increase that N load over time. Well monitoring by the town in the watershed is showing very high and increasing levels of nitrate (up to 6.2 mg L^{-1}, Craig Crocker, Centerville-Osterville-Marstons Mills Water Superintendent, personal communication) indicating the potential for increased N flows in the future. The Skunknett River currently flows through the ASRWS in 2.2 hours, permitting little time for natural N uptake and removal processes which occur during contact of water with sediments. The rapid flow scours stream sediments of organic material, further decreasing N removal. The present residence time of the river (as determined in the 2004 Hamersley study) in the Sanctuary is too low to allow significant removal. Restoring the former ponds and raising the level of Mill Pond could increase the residence time of the Skunknett River by eleven-fold. Summer total nitrogen removals under these conditions might approach 3,400 kg N y^{-1}. Summer reductions of TN flows into Scudder Bay resulting from pond restoration could be the equivalent of the N output of 565 houses. Although our preliminary study demonstrates the potential feasibility of hydrological manipulations in the ASRWS in mitigating N flows to Scudder Bay, any such manipulations would be require further topographical, wildlife, land use, and water quality data, as well as agreements with the landowner, Massachusetts Audubon.

In addition to the study on nitrogen fluxes and mitigation strategies in the Audubon Skunknett River Wildlife Sanctuary (Hamersley, 2004) up-gradient of the Centerville River System, a Draft Environmental Impact Report (DEIR) was developed by the Woods Hole Group in December 2003. The DEIR was developed in regards to a planned dredging of the Centerville River portion of the System as well as associated Craigville Beach nourishment activities. The DEIR focused on the Town of Barnstable developed two phased project approach to conduct maintenance and improvement dredging in the Centerville River/East Bay estuarine system. The proposed dredge project was initiated in September 2000 with the submittal of an Environmental Notification Form (ENF) to the Massachusetts Environmental Policy Act (MEPA) Unit. The ENF specified a two phased approach with a request for a waiver from the requirements of an EIR for Phase I of the project. The Phase I record of decision waiving the EIR requirements for Phase I of the project was issued in April of 2001.

Phase I of the Centerville River dredge and beach nourishment project including dredging material from the Centerville River west of the confluence of the estuarine reach of the Bumps

River and Centerville River. The Phase I dredging would extend into East Bay including removal of material from the East Bay inlet channel adjacent Dowes Beach. Dredge planning, engineering and permitting was completed by October of 2002 and dredging by the Barnstable County dredge commenced that fall. During the initial part of the Phase I dredge more than 20,000 cubic yards of sand was removed from the Centerville River leading to East Bay and that sand was subsequently used to nourish the Long Beach barrier separating Centerville River from Centerville Harbor. An additional 10,700 cubic yards of silty material was planned for removal from East Bay in the fall/winter of 2003 and subsequent dewatering and disposal.

Phase II of the dredge project involved additional maintenance and improvement dredging of the Centerville River east of the confluence of the Bumps River and Centerville River and extended into the most upgradient salt marsh areas (Centerville Marshes). Phase II of the overall project was the basis of the DEIR as required by the Secretary's Certificate on the ENF issued in March of 2001. The Phase II portion of the project was also required to be reviewed as a District of Regional Impact as specified under the Cape Cod Commission Act, Section 12(i). Under Phase II, an estimated 31,180 cubic yards of sediment would be removed from the eastern end of the Centerville River. Analyses of sediment disposal alternatives as well as environmental impact studies were conducted under the DEIR to elucidate preferred design and construction approaches for the dredge project. Sandy sediments would be used for beach nourishment (Long Beach and Craigville Beach). Silt/sand sediments would be dewatered in basins constructed on Craigville Beach and the sandy fraction of the dewatered sediments would be used for nourishment of Craigville Beach while silty sediments would be transported to a waste recycling facility in Sandwich, MA. The strictly silty sediments removed from the Centerville Marshes area of the system would be transported to the waste recycling facility for reuse.

As part of the DEIR, a summary of the existing environment was conducted combining a variety of data findings from studies carried out prior to initiation of the dredge project. Based on the summary provided in the DEIR it is apparent that the bathymetry of the Centerville River system had been characterized on 5 separate occasions between 1930 and 1969. Nearly twenty five years elapsed before the next bathymetric survey was conducted in 1996 as a condition survey for development of a hydrodynamic model of the Centerville River system (ACI, 1996). The 1996 hydro model was developed to examine tidal flushing characteristics within East Bay and Centerville River estuary with specific attention being given to the effects of proposed dredging on existing and future conditions. The MEP Technical Team captured the most recent elements of the historical record on bathymetry of the Centerville River system as well as details of the dredging activity in the system as has occurred in the past several years such that this knowledge could be incorporated into the development of the MEP hydrodynamic model. Moreover, details of the ACI, 1996 hydrodynamic model have also been captured by the MEP Technical Team in order to leverage any pertinent information generated under that effort which may be useful in the MEP analysis of the Centerville River System.

In addition to the summary of bathymetric data collection and description of the results of the 1996 hydrodynamic model runs for the Centerville River system, the DEIR also presents a discussion of the water quality characteristics of the estuarine system. It suffices to say that a large part of the discussion on water quality in the Centerville River system is based on the water quality monitoring program developed by the SMAST-Coastal Systems Program for the Town of Barnstable and in support of the Massachusetts Estuaries Project. An ancillary sampling program undertaken specifically in support of Phase II of the dredging project was developed and described in the DEIR. This dredge related sampling program focused primarily on nutrients within sediments. The sediment nutrient sampling program was developed and

executed by Dr. Dror Angel from the Department of Civil Engineering located at the Massachusetts Institute of Technology (MIT). The purpose of the sediment sampling program was to quantify the nutrient content of bottom sediments in the Centerville River system and to evaluate the extent to which nutrients could be released during resuspension of these sediments during a proposed dredge event. While this information is useful to the purpose that it was intended (i.e. dredging impacts), it does not relate to nutrient release associated with the undisturbed sediments of an estuarine basin.

While the DEIR covers a wide variety of other environmental factors that are of general interest, it does include specific information on shellfish and other invertebrates present in the system that was of interest to the MEP given the MEP's data collection on benthic infauna as a biological indicator of habitat health. A shellfish and benthic survey was developed in support of the DEIR and the proposed Phase II dredge project. The shellfish and benthic survey was conducted during August and September of 2003. A series of survey transects were established at 300 foot intervals across the Centerville River system west to east starting at the confluence with the Bumps River and extending up to the Centerville Marshes area. Shellfish and benthic data was collected at a total of 21 transects with three benthic sampling stations located along each transect. Sampling was conducted with rake hauls and clam rakes. As summarized in the DEIR, sections of Centerville River show signs of well oxygenated sediments that contain abundant benthic life including shellfish, *Mercenaria* and other species. Based on the DEIR benthic survey, other areas of the Centerville River system show signs of reduced flushing, anoxic sediments (black and sulphidic) and an embayment bottom with reduced and, in some instances, depopulated of benthic infauna. This information has been captured and considered by the MEP for use as appropriate.

The common focus of the Town of Barnstable Water Quality Monitoring Program effort has been to gather site-specific data on the current nitrogen related water quality throughout all the embayments of the Town (including the Centerville River System) to support evaluations of observed water quality and habitat health. This multi-year effort was initiated in 2001 for the Centerville River, with support from the Town of Barnstable and technical assistance from Three Bays Preservation and the Coastal Systems Programs at SMAST-UMD. The Barnstable Water Quality Monitoring Program in Centerville River developed a data set at sampling stations (Figure II-1) that elucidated the long-term water quality of the river system. Additionally, as remediation plans for this and other various systems are implemented throughout the Town of Barnstable, the continued monitoring is planned to provide quantitative information to the Town relative to the efficacy of remediation efforts. The MEP effort builds upon the water quality monitoring program, previous hydrodynamic evaluations conducted during the development of the EIR developed for the Centerville River Dredging Project and water quality analyses conducted by SMAST. Additionally, the MEP approach includes high order biogeochemical analyses and water quality modeling necessary to develop critical nitrogen targets for the Centerville River System.

The Town of Barnstable Water Quality Monitoring Program provided the quantitative water column nitrogen data (2001-2005) required for the implementation of the MEP's Linked Watershed-Embayment Approach. The MEP effort also builds upon previous watershed delineation and land-use analyses and the embayment water quality and eelgrass surveys. This information is integrated with MEP higher order biogeochemical analyses and water quality modeling necessary to develop critical nitrogen targets for the Centerville River Estuarine System. The MEP has incorporated all appropriate data from all previous studies to enhance the determination of nitrogen thresholds for the Centerville River System and to reduce costs to the Town of Barnstable.

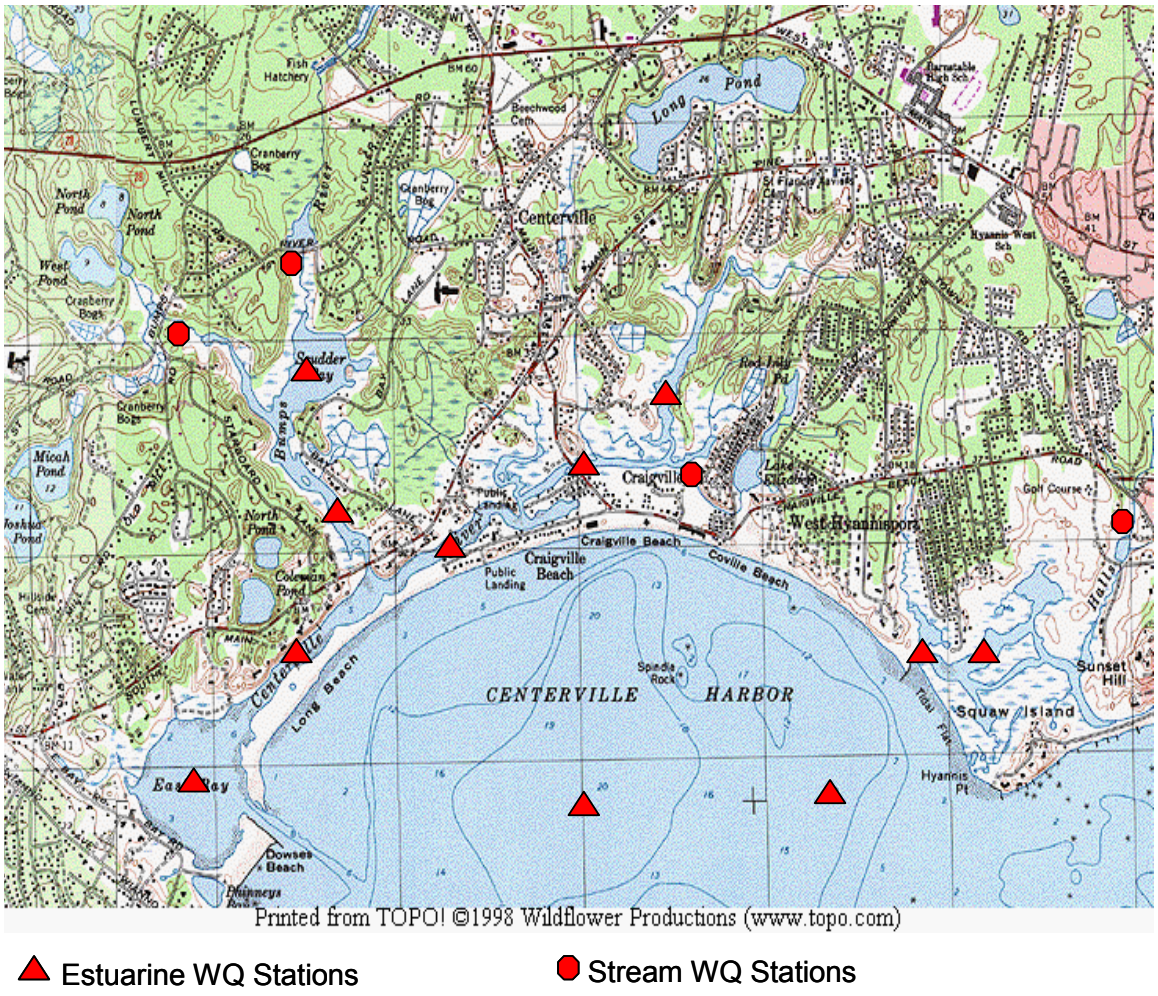

Figure II-1. Town of Barnstable Water Quality Monitoring Program. Estuarine water quality monitoring stations sampled by the Town and volunteers. Stream water quality stations sampled weekly by the MEP. Halls Creek along the eastern shore of Centerville Harbor will be assessed in a future MEP Technical Report on the Lewis Bay System.