

## II. PREVIOUS STUDIES RELATED TO NITROGEN MANAGEMENT

In most marine and estuarine systems, such as the Popponesset Bay embayment 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 eutrophication management approach via the reduction of nitrogen loads 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).

Until recently, 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 Popponesset Bay System.

A major component of the MEP nutrient analysis is the evaluation of hydrodynamics within the estuarine system. A two-dimensional hydrodynamic and water quality model was previously developed by Aubrey Consulting, Inc. (ACI, 1994). The purpose of this modeling effort was to assess potential impacts of nitrogen loading resulting from the proposed expansion of a sewage treatment plant. Field measurements of water elevations and bathymetry were taken to parameterize the hydrodynamic modeling effort; however, dispersion coefficients for the water quality modeling portion of the study were based upon previous studies of similar estuaries. The water quality modeling portion of the analysis utilized simplified assumptions regarding the incremental effects of increasing nitrogen loads to the estuarine system. It did not include a rigorous evaluation of all nitrogen sources to the estuary and did not include nitrogen sinks. The MEP analysis presented in this report provides a comprehensive analysis of nutrients within the Popponesset Bay estuary; therefore, results from the less rigorous 1994 analysis have been superceded.

Results from the 1994 hydrodynamic modeling study of flushing rates within the Popponesset Bay estuary indicate that central Popponesset Bay is relatively well flushed, since Popponesset Bay is generally shallow and the tide range is significant relative to embayment depth. At the time of this pilot hydrodynamic study greater than 50 percent of the water within the estuary was exchanged during a typical tidal cycle. The sub-embayments (located within the upper portions of the estuary system) to Popponesset Bay, however, show long residence times and receive a high percentage of the nutrient load to the Popponesset Bay system.

Following the initial hydrodynamic modeling effort, the Town of Mashpee, through the Mashpee Waterways Commission, funded a hydrodynamic study focusing on the effects of dredging on tidal flushing within the tidal portion of the Mashpee River (Hamilton, 1996 and 1998). Additional data was utilized to parameterize this model, including updated tide data from 1997 and updated bathymetry data from 1996. Initial modeling efforts (Hamilton, 1996) indicated a measurable reduction in the Mashpee River residence time as a result of dredging, indicating a potential water quality improvement. In later communications (Hamilton, 1998), this

conclusion was changed to indicate that feasible dredging scenarios do not significantly benefit Mashpee River flushing. Although the 1998 study indicated minor improvements to the hydrodynamic model, it is unclear how these modifications were responsible for the substantial change in model results.

For the MEP modeling analysis, the data from the previous studies were evaluated relative to the needs of the Linked Watershed-Embayment Model. Bathymetric data associated with the 1994 study was cursory and was not collected relative to a known tidal datum (e.g. NGVD29) as required for MEP. In addition, the tidal information also was not related to a known tidal datum, rather the tide data was related to a computed mean tide level, which is the average water elevation from the 30-day record. These data shortcomings and recent alterations to the system bathymetry (specifically in the vicinity of Popponeset Bay inlet) necessitated the collection of both bathymetry and tide data to support the MEP analysis.

Based on the above findings, a revised hydrodynamic analysis of the Popponeset Bay system, biological and chemical measurements, and a water quality model were developed that used the tidal flushing inputs and simulated the calculated and measured nitrogen loads to the embayments. This model was then calibrated in a process that rationalizes the resulting calculated water column concentrations with measured values from monitoring programs over the past four years. The water quality model then becomes a predictive tool for evaluating the effects of various nitrogen loading scenarios on nitrogen concentrations in the embayments.

The concern about excessive nitrogen loading to the water bodies in the Mashpee study area is evidenced by the number of studies and analyses conducted over the past 10 years. As early as 1984 attention was being given to possible water quality problems within Popponeset Bay whereby James Begley of the D.E.Q.E. Shellfish Sanitation Section identified excessive levels of coliform bacterial contamination in the Mashpee River. This finding promptly led to closure of the Mashpee River to shellfishing. Contamination problems in Popponeset Bay were further investigated by K-V Associates, Inc. on behalf of the Mashpee Planning Department and Planning Board. Initial concerns over contamination problems in Popponeset Bay resulted in the development of a Interim Report (October 1987) entitled "Sources of Bacterial and Nutrient Contamination into the Mashpee River, Santuit River and Shoestring Bay." This initial report was followed by a second report also completed by K-V Associates, Inc. in 1988 that examined storm discharges (under winter conditions) to Popponeset Bay as well as undertook recharge zone delineations for the Mashpee River, Quaker Run and the Santuit River. In addition, data on Mashpee River flow and water quality was developed and compiled by Goldberg-Zoino and Associates in a July 1988 report prepared in conjunction with the Mashpee Sewer Commission's work on a sub-regional wastewater treatment facility proposed to be located adjacent to the former Mashpee landfill. It was clear from the initial studies that the Popponeset Bay System is nutrient overloaded. Based upon water quality indicators (chlorophyll a, total nitrogen, bottom water dissolved oxygen) much of the System would be classified as eutrophic (KV Associates 1984, Howes and Schlezinger 1997, 1998). This section summarizes these studies in chronological order to help put the present study in historical perspective.

One of the first identified studies that address nutrient contamination problems in Popponeset Bay is a Cumulative Impact Assessment performed by K-V Associates, Inc. (1991). The analysis presented in the K-V assessment (1991) supported a plan to reduce and control sources of contamination in the Mashpee River and Santuit River/Shoestring Bay estuaries to Popponeset Bay. However, the overall nutrient data was somewhat limited and suffered from inadequate method detection limits. In addition, the significant development that

has occurred in the intervening years suggests that these data do not reflect current conditions. In addition, this study focused primarily upon the upper bay sub-embayments and the rivers. It did not include a comprehensive land-use analysis and did not account for nitrogen dynamics within the aquatic systems. However, it did point out many of the nutrient issues that continue to be relevant and are to be examined through the MEP analysis.

The Cape Cod Commission (CCC) undertook the Cape Cod Coastal Embayment Project that indicated that nutrient loading to the Popponesset Bay system, which includes the Mashpee River, Shoestring Bay, and Ockway Bay, is a significant problem. The data was based upon the 1996 watershed delineations. Due to the difference in watershed areas, updating of the land-use analysis and refinement of the watershed nitrogen loading model component of the MEP approach, the results from the MEP are different and supersede those of this earlier study.

The most recent survey of nutrient related water quality in the Popponesset Bay embayment system was performed by the University of Massachusetts – Dartmouth, School for Marine Science and Technology (SMAST) (Howes and Schlezinger, 1997). The goal of the 1997 water quality survey was to evaluate the relative nutrient related ecological health of the major component embayments to the Popponesset Bay system and determine if there was nutrient related degradation of the sub-systems to Popponesset Bay. Sampling for the survey was conducted during the summer when eutrophication impacts are generally the greatest in Cape Cod embayments as a joint effort by the Town of Mashpee, SMAST, and private citizen volunteers. The survey was conducted during the summer of 1997 and involved 5 periodic field sampling events through the period of July 31 to September 12, 1997. Major findings of the 1997 water quality survey indicate: 1) nitrogen levels within the Popponesset Bay system are significantly higher than the incoming water from Nantucket Sound with resultant enhancement of phytoplankton biomass, 2) both biomass and total nitrogen (TN) are more than 10 and 2 fold higher, respectively, than the high quality water from Nantucket Sound, 3) there is a distinct nutrient and phytoplankton biomass (chlorophyll-a) gradient within the Popponesset Bay system with highest levels for each being Mashpee River>Shoestring Bay>Ockway Bay>Central Bay>Nantucket Sound, 4) oxygen depletions of bottom waters of the sub-embayments to Popponesset Bay is relatively wide spread and frequent within the Mashpee River, Ockway Bay, and Shoestring Bay. At the time of the 1997 survey the central portion of Popponesset Bay still exhibited relatively high water quality.

The water quality data from this preliminary water quality study have been incorporated with data collected in subsequent years by the same group, the Popponesset Bay Water Quality Monitoring Program, which includes private citizens, the Mashpee Shellfish Department, Mashpee Harbor Master, Mashpee Waterways Commission, Mashpee Watershed Management Committee, Cotuit Waders, and Barnstable DPW (Nutrient Management Committee). The MEP has incorporated all appropriate data from all previous studies to enhance the determination of nitrogen thresholds for the Popponesset Bay System and to reduce costs to the Towns of Barnstable and Mashpee.