University of Massachusetts Dartmouth
The School for Marine Science and Technology

Massachusetts Department of Environmental Protection

Technical Memorandum
Massachusetts Estuaries Project

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Re: Massachusetts Estuaries Project Technical Team Response to the RPS ASA Review of the Draft Final Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Nauset Estuary System, Orleans and Eastham, Massachusetts

Date: December 4, 2012

Milestones:		
	MEP Draft Threshold Report submitted to MassDEP:	November 3, 2011
	DEP/MCZM/BBP Review Received:	December 21, 2011
	MEP/SMAST Response Submitted to MassDEP:	May 24, 2012
	RPS ASA Review Received by MEP Tech Team:	November 30, 2012
	MEP Technical Workshop on Nauset Estuary Report:	December 4, 2012

In response to the comments generated by the co-review undertaken by the United States Department of Environmental Protection (USEPA), the Massachusetts Office of Coastal Zone Management (MCZM) and the Massachusetts Department of Environmental Protection (MA DEP) regarding the Draft Final Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for the Nauset Estuary System, Orleans and Eastham, Massachusetts, the MEP Technical Team provided responses to said comments, revised the Draft Report per the comments and re-submitted the MEP Threshold Report to the Mass DEP for circulation to the Town of Orleans. Subsequently, the Town of Orleans was provided the MEP Threshold Report by the MassDEP for its review in advance of a technical presentation to be held by the MEP Technical Team (December 4, 2012). The technical workshop is provided

for the benefit of Town staff and the public in order facilitate their understanding of the results of the analysis for the Nauset Estuary, address questions and provide clarification. In advance of the MEP technical workshop, the Town of Orleans retained the services of RPS ASA for a review of the MEP Threshold Report for the Nauset Estuary. The Town of Orleans provided the findings of the RPS ASA review to the MEP Technical Team two business days in advance of the MEP technical presentation scheduled for December 4, 2012. Provided below is an initial and formal response to the most pertinent comments provided to the MEP Technical Team by the RPS ASA reviewers. The purpose of this document is to clarify points raised and correct erroneous statements made in the provided review, so that the Town might proceed with a more accurate understanding of the Nauset analysis.

It is the desire of the MEP Technical Team to continuously seek improvement relative to the clarity of the material presented in the threshold reports. The MEP Technical Team is not obligated by the MEP project protocols to provide a formal point by point response to external third party reviews, however, in the case of the RPS ASA review, the MEP Technical Team determined it was necessary to do so due to the numerous fundamental misinterpretations of information provided in the MEP Technical Report for the Nauset Estuary and associated scientific literature. The Technical Team felt that providing a companion response document to the RPS ASA review document would best serve the public process in which many towns on Cape Cod are current engaged. Note that minor comments not associated with substantive technical issues and editorial points are not addressed in the present document, however where appropriate, edits will be made in the final MEP Report.

The format followed below, states first a specific RPS ASA comment in *italics (*provided to the MEP Technical Team on November 30, 2012), followed by the associated MEP Technical Team response. The comments/responses are arranged by the MEP Chapters also noted by the RPS ASA reviewers and also refer to specific pages from the RPS ASA document.

MEP Reponses to RPS ASA Review of the MEP Nutrient Threshold Report for the Nauset Estuary, Town of Orleans, MA.

Regarding MEP Nauset Report Chapters 2, 3, & 4:

1. ASA comment:
p.4. *The 2000 Coastal Loading Nitrogen Project (Water Resources Office, Cape Cod Commission) stated that 60% of the nitrogen loading to Salt Point was derived from a landfill which was capped in 1997. The delay between the capping and the impacts to water quality are likely not encompassed in data presented in the Report, and if the source determinations are accurate, there should be improvement in water quality in Salt Pond.*

MEP Response:
The MEP assessment represents an extensive and comprehensive update on the system characterization for the Nauset Estuary, inclusive of Salt Pond and the Eastham landfill loading. The CCC assessment referenced did not have the benefit of the freshwater pond N attenuation data, the landfill site characterization data resulting from the capping (*e.g.*, area of refuse), or the updated MEP USGS groundwater modeling that is available in the MEP assessment. The inclusion of this information along with updated landfill monitoring data (all post-cap) allowed a much more refined characterization of system along with water quality data in the estuary and the freshwater ponds to check all watershed loading estimates. The substance in the MEP assessment limits the comparability of the two estimates and reinforces the need to disregard

the less robust older CCC assessment. In addition, as the landfill has been capped, it is clear that the groundwater plume will "wash out" and future loads (build-out) reflect this reduction. Note that the MEP existing load is what is reaching the estuary during the analysis period and future changes, either increases or decreases, are evaluated in the build-out analysis.

2. ASA comment:
pp. 5-6 The delineation of the watersheds for subsequent estimation of the groundwater discharges was done through the use of MODFLOW-2000 in collaboration with the USGS. The MEP 2005 watershed delineation notes a significant expansion of the watershed further into Brewster (Fig III-2, pg, 37) yet reflect a 60-acre decrease in total watershed area. These data are later used in the watershed loading model for nitrogen. The alignment of watershed flow data to stream gauge data (pg. 34, para. 3) and smoothing of model output data - watershed boundaries, present possible sources of error to the outputs. It appears to be implicitly assumed that all groundwater within the watershed reaches Nauset Estuary at the same rate, though studies by Kroeger and Charette (2008) indicate that in other areas of Cape Cod, the estuary may be bypassed completely and groundwater is discharged directly offshore. Evaporative losses also appear to be excluded from the water balance within the watershed. In light of this information, the apparent linearity between stream-flow and groundwater loading to the Estuary may not be entirely accurate.

MEP Response:
The USGS groundwater model provides the estuary and pond watershed delineations. Similar to the issues mentioned in the response above, the groundwater model is a substantial update to the understanding of the system, incorporating years' worth of water level measurements, geologic explorations, and refinements of glacial forensics. The comparison to past watershed delineations is limited because of the significant increase in the amount of data that has been incorporated into the MEP assessment.

Kroeger and Charette (2008) evaluated nitrogen loss at the groundwater discharge margin of Waquoit Bay. If anything, the data in the cited study reinforces discharge of the whole upgradient aquifer within a few meters of the coastline rather than indicating any sort of underflow (see particularly their Figure 2). The cited study reinforces different types of studies conducted all over the Cape (e.g. Cambareri and Eichner, 2003, Urish and McKenna, 2004, Walter, 2007, Millham and Howes 1994) that show small scale spatial and site-specific differences in groundwater discharge, but also show that at the scale of the Nauset Estuary groundwater discharging from the entire watershed or individual subwatersheds, enters the estuary in the nearshore region. Groundwater does not underflow the estuary unless there is some sort of geologic control altering the groundwater flow paths. ASA's comment is unsupported by the cited paper and also conflicts with available research throughout the Cape.

Finally, evaporative losses are included in all evaluations of flow. Recharge in the USGS groundwater models as stated in the MEP Report, which are the basis for watershed flows in the Nauset system, are 27.25 inches per year in the Monomoy Lens (Orleans and Brewster) and 24 in/yr in the Nauset Lens (Eastham). Since recharge is precipitation (~44 in/yr) minus evapotranspiration, loss of water to the atmosphere is built into the MEP watershed delineations and hydrological calculations. ASA's comment is unjustified.

3. ASA comment:
p.6. *Observational data over a 6-year period for septic removal efficiencies by Heufelder (2007)*

indicate that Title 5 septic median effluent concentrations were 19 mg L-1, rather than the 26 mg L-1 presented in the Pilot Study.

MEP Response:
Heufelder and others (2007) is a review of the nitrogen removal performance of 11 different types of innovative/alternative septic systems; there is no monitoring of conventional Title 5 septic systems included in this report. As all of the systems in this report are enhanced nitrogen removing septic systems, the effluent N concentration is lower than effluent N associated with standard Title 5 systems. The basis for ASA's criticism of the MEP septic nitrogen loading factor is based on a misinterpretation of their cited report (Heufelder et al. 2007).

As stated clearly in the MEP report, the septic nitrogen loading factor relies on a per capita nitrogen loading rate that has been clearly defined in a number of studies, including the ones that are referenced. These studies include not only evaluation of watersheds to surface waters, but also to public water supply capture areas. Additional references evaluating groundwater downgradient of septic systems also confirm that the MEP factors are appropriate. ASA's comment is based upon a misinterpretation of how MEP septic system N loads are evaluated.

4. ASA comment:
pp. 6-7 *In the determination of the attenuation in Depot and Muddy Ponds, the calculated values were reported as*

> *…based on the available water quality data, these ponds have calculated nitrogen attenuation rates of 82% and 73%, respectively. In order to address some of the data uncertainties (e.g., lack of sediment samples to evaluate the impact of sediment regeneration on surface TN concentrations), MEP staff rounded the rates down to slightly more conservative percentages: 75% and 70%, respectively.(pg. 58, para. 1)*

Later in the Report it assumed that there is no vertical gradient in nutrient concentrations for modeling purposes. If the gradient is not critical to the validity of model results that include the benthic sources of nitrogen, it is unclear why these attenuation factors were reduced.

MEP Response:
ASA seems to be mixing up the estuary and the ponds. As stated, the pond N attenuation factors were slightly reduced to address uncertainties about the impact of sediment regeneration on the measured water quality in the ponds. The reference to "no vertical gradient in nutrient concentrations" does not relate to the ponds and is therefore confusing.

5. ASA comment:
p.7 *Work by Westgate (2000) using nitrogen isotopes to assess nitrogen removal within the watershed concluded that the main nitrogen impacts to the watershed are from sources within 480 meters to 730 meters of the shore, with up-gradient sources dramatically diluted by clean groundwater.*

MEP Response:
Westgate (2000) proposes that nitrogen from septic systems disappears completely within the stated travel distance. The underlying problem with the Westgate paper is that the groundwater travel paths are poorly defined and close reading shows that the wells shown in the figures are not in the same plane(flowpath). Given this problem, the paper's conclusions are not supported nor is ASA's reliance on these conclusions. In contrst, the MEP relies on numerous detailed

studies by a wide range of researchers from the USGS and other institutions that demonstrate that nitrogen is transported relatively unattenuated in oxidized sandy outwash aquifers, particularly those on Cape Cod.

6. ASA comment:
p.7 Kroeger and Charette (2008) indicate that not all groundwater flow in the region will go through the embayment, suggesting non-linearity and non-uniformity in groundwater loading to the embayment.

MEP Response:
See response to comment #2.

7. ASA comment:
p.7. The discussion of bio-availability of the TN load would benefit from the additional analysis, as the bioavailable components are those that ultimately influence water quality. It seems that the whole of the nitrogen loading is assumed to be bio-available, when attenuation within the watershed will not only decrease the amount of nitrogen reaching the embayment but also change the nature of the material.

MEP Response:
ASA's comment seems to misunderstand the MEP watershed loading, as well as being internally inconsistent with their own previous comments. The MEP approach uses TN in the watershed nitrogen loading because of the rapid transitions between N forms upon encountering carbon sources, such as pond, river, or estuarine margins, as well as the general predominance of N as nitrate-N in the Cape's highly oxidized general aquifer. Similarly, ASA commented on attenuation rates on p.6 which should have internalized that the MEP approach does include factors that necessarily "*decrease the amount of nitrogen reaching the embayment*."

<u>MEP Nauset Report Chapters 5:</u>

1. ASA comment:
The application of the RMA models in the MEP Linked Model System is flawed in that it does not address potential changes in the physical layout of the beaches, inlet, and bathymetry due to the well documented dynamic nature of Nauset Harbor. At a minimum a sensitivity analysis should be performed to evaluate the range of nitrogen thresholds under different physical configurations.

MEP Response:
The calibrated and validated MEP models are for existing conditions, *i.e.* conditions at the time of the MEP analysis. Future, presently unrealized conditions are part of planning scenarios that are run as part of the MEP analysis (build-out, no anthropogenic, threshold attainability N loads). While potential changes in inlet structure, bathymetry and other changes can be modeled, they are not part of this phase of the MEP work. Instead, they would be run as part of the Nutrient Planning Process as noted in the WHOI report mentioned by ASA. Therefore, since the existing conditions were modeled, there is no flaw in the approach or in its applications. The comment suggests a misreading of the MEP process and is without merit.

2. ASA comment:
The Report incorrectly states "the observed astronomical tide is therefore the sum of several individual tidal constituents, with a particular amplitude and frequency." (pg. 80, para. 5) The word "frequency" should be replaced with "phase".

MEP response:
The phase of each particular tide constituent is only important when the tide elevation at a specific time is needed. It is correct to say that each constituent has an amplitude and frequency. The frequency of the principle lunar semi-diurnal M2 tide is 0.0805 hr-1 (12.42 hour period). The frequency of the main solar diurnal K1 tide is 0.0419 hr-1 (23.93 hour period). ASA's comment is simply not correct.

MEP Nauset Report Chapters 6:

1. ASA comment:
The calibration of the model by tuning the dispersion coefficients to reproduce the analytical nitrogen data (page 111) is not a conventional approach. Nitrogen is non-conservative, as mentioned on page 108. Typically, the model dispersion coefficients would be calibrated to salinity, a conservative tracer.

MEP Response:
The MEP water quality model (as stated in the report) is calibrated to measured spatially distributed TN and validated using measured salinity. Since the model must match both TN and salinity, the comment is misleading. The approach has been fully vetted by independent water quality professionals, who agree that the use of both TN and salinity provides for a robust output and a model that can be relied on for predictions of alternative scenarios. A major issue with using salinity alone to calibrate the model is the fact that salinity measurements between the ocean and the uppermost reaches of the system vary within 2 ppt. This is typical of many estuaries on Cape Cod that have few surface water inputs. The small gradient is not enough to lead to a meaningful calibration of the water quality model.

2. ASA comment:
"...the time period of the water quality model simulation appears short relative to the timescales of nutrient dynamics within the embayment, unless offshore sources are the predominant source of nitrogen to the region. The impact of nitrogen loading to the embayment is seasonal in nature, and thus there are more dynamic process affecting water quality than can be modeled in a 14.5 day time period. It is not clear whether the dynamics of the system are being captured or if the calibration of the model to total nitrogen data has obscured these processes."

MEP Response:
The model is run initially to the point where it achieves a dynamic equilibrium. This model spin-up period is a full month. The 14.5-day period of model output used in this analysis comes after the month-long spin up period. This two-week period represents the typical range of tides in the system between the twice-monthly neap to spring tide cycle.

3. ASA comment:
The assumption that there are no vertical gradients in nitrogen concentrations for modeling purposes, and thus rapid mixing within the embayment, does not appear to be supported

elsewhere in the Report. This assumption seems to contradict the bottom water DO values presented, as a water-body without stratification would be completely mixed, and low oxygen levels would not likely be observed at depth.

MEP Response:
The periods when stratification occurs in an embayment such as Town Cove are infrequent. When stratification occurs it is typically of short duration followed by complete vertical mixing. While this can result in oxygen depletion, the duration is generally insufficient to create significant gradients in nitrogen species. The MEP analysis focuses on typical conditions in the system.

MEP Nauset Report Chapter 7:

1. ASA comment:
In the review of a statistical analysis of the data collected by the Town of Orleans Water Quality Monitoring Program (Fiegel, 2011), the following is stated:

> *The dissolved oxygen levels throughout the Estuary exceed the State water quality criterion of 6 milligrams per liter (mg/L) with the exception of samples from the bottom of Mill and Salt Ponds, and at the bottom of the Yacht Club (closed end of Town Cove). (pg.18 para. 3)*

and

> *"…MEP water quality monitoring measurements do not seem to support the assertion that a significant reduction in septic nitrogen discharge to the Estuary will improve water quality throughout the system, especially, as dissolved oxygen is already in a healthy state throughout the surface and middle depths."*

In later sections of the Report, DO measurements for a single month (July 2003) of bottom waters are presented as evidence that water quality impairments are routinely observed in DO and chlorophyll-a (chla) in Salt Pond, Town Cove, and Mill Pond. Although these data indicate that low DO and high chl-a levels are observed for a period of time, a much larger dataset should be used to truly assess the state of DO water quality. As it is presented, it is only evident that July 2003 showed hypoxic conditions in several of the Ponds. Water quality issues were observed in other parts of New England at the same time (Greenwich Bay fish kill in Rhode Island) and thus it is unclear whether larger scale meteorological factors played a role in the observed conditions at these ponds.

The report also notes that the offshore nitrogen levels are high by a factor of two compared with other embayment systems except for the Pleasant Bay system just south of the Nauset System.

MEP Response:
Specific to the reference (Fiegel, 2011. Statistical Analysis of Multi-year Water Quality Monitoring Data 2003-2010, the MassDEP evaluated the water quality analysis report (letter to Town of Orleans 2011) some of which is provided here is as it relates to the reviewers comment:

With respect to the assertion that DO levels exceed water quality standards, Mr. Fiegel relies on an average of measurements at each sampling station. Average DO values are not appropriate in ascertaining compliance with standards. First, the Surface Water Quality Standards at 314 CMR 4.00 state that for Class SA waters DO "shall not be less than 6.0 mg/L".

Secondly, while an average value may "meet" a numerical criterion, it ignores the fact that the average value represents periods when DO is higher and lower than that average value. It is the period of lower values that is of concern because short periods of low DO are generally sufficient to result in adverse ecological consequences for the system. In addition, periodic sampling such as was conducted by the Task Force, while good for determining if oxygen depletion is occurring, typically does not capture the lowest oxygen levels due to the high frequency variation that DO exhibits in many estuarine basins. Therefore, it is more useful from an assessment standpoint to evaluate the grab samples in concert with the time series DO measurements, of which type presented in the Nauset MEP report. It should be noted that the open water basins of Nauset as sampled by the Task Force did show periodic low oxygen in bottom waters. Contrary to the suggestion of Mr. Fiegel to rely on surface water oxygen levels, it is the bottom water that is in direct contact with the sediments, critical habitat for animals that play key roles in the estuarine food web.

Further relative to the offshore boundary station issue:

Offshore sampling stations are established to set boundary conditions for modeling and are chosen to represent offshore waters which are relatively uncontaminated from land based nitrogen. Throughout the MEP region, these waters have been located in the Atlantic Ocean, Vineyard Sound, Nantucket Sound or the open waters of Buzzards Bay and generally have displayed total nitrogen levels ranging from 0.25 to 0.31 mg/L. The median levels at Station WMO-41, the boundary condition station in this sampling effort, shows higher nitrogen values than in virtually all other offshore sampling stations. This appears to be an anomalous condition likely stemming from the sampling during the outflow from the estuary. Sampling offshore of Pleasant Bay, just to the south, had similar problems until the sampling was shifted to flood tide.

Further, the contention by RSP ASA that 2003 was an anomolous year for estuarine DO levels and therefore the Nauset oxygen analysis is atypical is not supported by the evidence. First, ASA contends that since there was a significant and large fish kill in Greenwich Bay (August 22, 2003), a tributary to Narragansett Bay, the oxygen levels in Nauset in June and July were also atypical. As the Greenwich Bay hypoxic event was due to a meteorological event triggering low oxygen in a bay that was poised to go hypoxic due to its high nitrogen loading, it is just what the MassDEP is trying to prevent in Cape Cod estuaries. RSP ASA does not explain why an event in Narragansett Bay in late August is related to meteorological conditions in June and July on Cape Cod. Most importantly, the analysis by the MEP has shown that bottom water oxygen levels in the terminal ponds and Town Cove are found in multiple years as well as by the grab samples and moored oxygen sensors in 2003. Therefore, it is clear that low oxygen is a typical stressor to animals and plants within multiple basins of the Nauset Estuary.

References:

Millham, N.P. and B.L. Howes. 1994. Patterns of groundwater discharge to a shallow coastal embayment. Marine Ecology Progress Series 112:155-167.

Cambareri, T.C. and E.M. Eichner. 1998. Watershed Delineation and Ground Water Discharge to a Coastal Embayment. Ground Water. 36(4): 626-634.

Urish, D.W. and T.E. McKenna. 2004. Tidal Effects on Ground Water Discharge Through a Sandy Marine Beach. Ground Water. 42(7): 971-982.

Walter, D.A., 2008, Use of Numerical Models to Simulate Transport of Sewage-Derived Nitrate in a Coastal Aquifer, Central and Western Cape Cod, Massachusetts: U.S. Geological Survey Scientific Investigations Report 2007–5259, 41 p.