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MEP Technical Memo

To: David Young, CDM
Frank Sampson, Chair, Harwich Water Quality Management Task Force

From: Ed Eichner, CSP/SMAST
Brian Howes, CSP/SMAST
Sean Kelley, ACRE
John Ramsey, ACRE

Date: June 25, 2010

Re: Updated water use and Muddy Creek nitrogen attenuation and nitrogen loading to Pleasant Bay

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On behalf of the Town of Harwich, Camp Dresser & McKee (CDM) requested a scenario using the linked Massachusetts Estuaries Project (MEP) models for Pleasant Bay to assess the impact of updated information on the findings for Round Cove and Muddy Creek. The scenario results documented in this Technical Memo include the inclusion of the following updated information:

- updated average Harwich water use based on 2004 to 2007 data,
- updated Harwich land use coverages from 2006, and
- updated nitrogen attenuation from the 2008 SMAST analysis of Muddy Creek.

A summary of the scenario development and its results are described below.

Scenario Development

During the collection of information for the development of the MEP linked models for Wychmere Harbor, Saquatucket Harbor, Allen Harbor, and the Herring River, MEP staff obtained 2004 to 2007 water use information from the Harwich Water Department for parcels throughout the Town. This enhanced the prior Pleasant Bay nitrogen loading analysis, which had access to only the 2004 water-use data from the Water Department at the time of the development of the Pleasant Bay MEP linked model (Howes, *et al.*, 2006)[1]. Similarly, the Town of Harwich provided updated land use information for the review of all systems. The Pleasant Bay MEP assessment is based on 2004 Harwich land use data, while the other MEP systems in town will be based on 2006 land use data. The Town of Harwich and CDM wanted to have a consistent and comprehensive basis for the current Comprehensive Wastewater Management

[1] Howes B., S. W. Kelley, J. S. Ramsey, R. Samimy, D. Schlezinger, E. Eichner (2006). Linked Watershed-Embayment Model to Determine Critical Nitrogen Loading Thresholds for Pleasant Bay, Chatham, Massachusetts. Massachusetts Estuaries Project, Massachusetts Department of Environmental Protection. Boston, MA.

Planning effort and requested that a MEP scenario be completed for Pleasant Bay that uses the 2006 land use base and 2004 to 2007 water use that is used for the assessment of all of the other MEP estuaries within the town.

In addition, MEP Technical Team members completed a 2008 assessment of Muddy Creek (White, *et al.*, 2008)[2]. This assessment, which was completed for the Pleasant Bay Alliance, included collection and analysis of sediment nitrogen regeneration, wetland characterization, water quality analysis, and nitrogen exchange measurements between the upper and lower basins of Muddy Creek. This assessment is a much more detailed and comprehensive review of Muddy Creek than was possible during the MEP assessment and allowed for an updated assessment of nitrogen attenuation in the Upper and Lower portions of Muddy Creek. The Town of Harwich and CDM requested that the findings from the 2008 Muddy Creek assessment be incorporated into the scenario with the Town's updated water use and land use. The requested scenario does not modify the inlet to Pleasant Bay to include the 2007 breach nor does it change the inlet culvert configuration or size into Muddy Creek.

In order to integrate the updated information, MEP Technical Team members were required to check the calibration and validation of the MEP Linked Models for Muddy Creek and Pleasant Bay. This step checked the effects of incorporating the new information and compared these results to the available water quality and salinity data to ensure that any significant changes did not cause unacceptable variability in the comparison of model results to collected field data. This step was especially important for the Muddy Creek area where much more refined data were incorporated. These checks showed that modest re-calibration was required in Muddy Creek (mainly as a result of the new attenuation rates) and that validation of the model was sustained.

MEP Scenario Results and Discussion

Based on the incorporation of the new information, watershed nitrogen loads for Muddy Creek and Round Cove increased (Table 1). Aside from the new water use, revised loads also include: a) changes in the treatment of both existing and buildout conditions at the Wequassett Inn (personal communication, Dave Michniewicz, Coastal Engineering, 6/26/08), b) load additions from farm animals, c) inclusion of a cranberry bog in Lower Muddy Creek that was previously excluded, d) inclusion of innovative/alternative septic systems in the Upper Muddy Creek subwatersheds, and e) updated land use coverages from 2006. These changes are consistent with updates provided as a result of data gathering for MEP assessments of other estuaries in Harwich.

After incorporating the revised nitrogen loads, the attenuation factors based on the more refined assessment of Muddy Creek were incorporated (White, *et al.*, 2008). The attenuation factor used for watershed nitrogen loading from Upper Muddy Creek is 57%, while the attenuation factor for Lower Muddy Creek is 2%. These attenuation factors are based on the measured water quality in Muddy Creek documented in the 2008 report and the revised watershed nitrogen loads completed for this scenario.

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[2] White, D., B. Howes, S. Kelley, J. Ramsey. 2008. Resource Assessment to Evaluate Ecological & Hydrodynamic Responses to Reinstalling a Water Control Structure in the Muddy Creek Dike. Report to the Pleasant Bay Alliance by the Coastal Systems Program-SMAST, University of Massachusetts-Dartmouth, New Bedford MA

The overall attenuated load for the upper Muddy Creek basin decreased (41%) mainly as a result of including the large measured attenuation in the upper basin (2008), while the attenuated watershed load for the lower basin increased by 27% (Table 2). Round Cove attenuated load increased by 48%. Overall, the updated attenuated watershed nitrogen load for the combined Muddy Creek decreases 10% and is similar to the MEP report, 16.59 kg d^{-1} and 18.46 kg d^{-1}, respectively. The net combined result of the changes in the watershed loads, attenuation factors, and more refined sediment characterization is that the overall Muddy Creek nitrogen load changes only very slightly: 2006 MEP Report nitrogen load is 22.16 kg d^{-1}, while the load in this revised scenario is 22.19 kg d^{-1}. The Round Cove overall load increases by 16% (from 12.82 to 14.83 kg d^{-1}).

It is also notable that the 2008 study found that Upper Muddy Creek sediments serve as a net nitrogen sink during summer conditions, while Lower Muddy Creek sediments are a net nitrogen source (see Table 2). The 2006 MEP report included the reverse assessment of the sediments in Upper (net source) and Lower Creeks (net sink). The main difference found in the more detailed 2008 assessment is due mostly to the very large nitrogen uptake in the uppermost brackish wetland, which was previously not measured. The 2006 MEP upper basin analysis was based upon measurement at a single location near this wetland.

Incorporation of the increased natural nitrogen attenuation in Upper Muddy Creek decreases the wastewater nitrogen that must be removed from its watershed to meet its threshold if wastewater is the only nitrogen source that is reduced (Table 3). The percentage of wastewater nitrogen that must be removed to meet the threshold decreases from 75% in the 2006 MEP analysis to 66% in this revised scenario. Lower Muddy Creek remains at 100% wastewater removal under the revised scenario and Round Cove increases from 40% wastewater removal to 64% removal. Round Cove's increase is largely due to an increase in the septic load based on the incorporation of the water use revisions.

When all loads, including septic wastewater, fertilizer, and stormwater runoff, are considered as sources for nitrogen removal to meet the threshold, the necessary percentage reductions in attenuated watershed nitrogen loads are different (Table 4) than if only septic loads are considered (see Table 3), but the relative relationships among the estuaries are essentially the same. Lower Muddy Creek has the highest required removal, which increased slightly in the requested scenario (from 75% to 80%), while Upper Muddy Creek has a slight drop in required removal (from 54% removal to 52% removal) and Round Cove has an increase in the required removal (from 30% to 53%). Although Upper Muddy Creek has an increase in the watershed load (see Table 1), this increase is largely offset by the better documented increase in system nitrogen attenuation. The opposite effect is seen in Lower Muddy Creek and Round Cove where the increased total watershed load increases the percentage of watershed load that must be removed.

Table 5 compares the threshold loads for bioactive nitrogen (DIN+PON) under the 2006 MEP Report and this updated scenario. As also shown in Table 4, the watershed threshold loads for Lower Muddy Creek and Round Cove generally did not change, but the watershed threshold load for Upper Muddy Creek decreased due to the increased attenuation in the system. The changes in the benthic fluxes due to the 2008 study also are noted.

In interpreting the results, it is important to consider that Muddy Creek is a heavily altered system, which previously was divided by a dike, and has a large restriction of tidal exchange at its outlet to Pleasant Bay due to a small culvert under Rt. 28. Tributary estuaries with large restrictions to tidal exchange (reduced flushing) have increased nitrogen levels over the similar systems with unrestricted tidal exchange. Extreme examples of the effect of tidal exchange on nitrogen levels can be seen in West End Pond (Gosnold) and Rushy Marsh (Barnstable), where removing all anthropogenic watershed nitrogen loading is insufficient to meet water quality restoration goals. The flushing rates in these systems are so low that even small amounts of entering nitrogen accumulate to produce high water column nitrogen levels and low oxygen conditions. While Muddy Creek is not at this level of restriction, it is virtually certain that much of its nitrogen related water quality "problem" results from its restricted tidal circulation.

The overall impact of incorporating all the Harwich changes, including updated land use and water use, incorporation of monitoring from innovative/alternative septic systems, loading from farm animals, Wequassett Inn wastewater clarifications, and the better characterization of Muddy Creek, is summarized as:

1) Lower Muddy Creek is not changed; the watershed threshold load remains the same and the required septic removal to meet the threshold remains at 100%.
2) Upper Muddy Creek has a slight improvement in nitrogen removal to meet the threshold. Incorporation of the better documented natural nitrogen attenuation in the Creek largely balances watershed nitrogen loading increases. The net result is that the watershed threshold load is reduced and the required septic removal to meet the threshold also decreases to 66%.
3) Round Cove watershed threshold load remains the same, but the addition of the modified water use has increased the watershed nitrogen load. The net result is that in order to meet the watershed threshold load, the required septic removal within the watershed increases to 64%.

Table 1. Comparison of Watershed Nitrogen Loads for Round Cove and Muddy Creek. A) Watershed nitrogen loads from Table IV-5 of the Massachusetts Estuaries Project Technical Report for Pleasant Bay (Howes, *et al*., 2006). B) Watershed nitrogen loads prepared for this scenario including the incorporation of updated water use and land use from the Town of Harwich. Muddy Creek attenuated loads do not include attenuation assigned to within the wetlands and sediments of the Muddy Creek.

A) 2006 MEP Pleasant Bay Technical Report Nitrogen Loads for Round Cove and Muddy Creek

		Pleasant Bay N Loads by Input (kg/yr):							Present N Loads		
Name	Watershed ID#	Wastewater	Fertilizers	Impervious Surfaces	Water Body Surface Area	"Natural" Surfaces	Buildout	% of Pond Outflow	UnAtten N Load	Atten %	Atten N Load
Round Cove	61,62 + MP	1157	175	154	77	54	347		1616		1607
Round Cove Estuary surface deposition					62				62		62
Muddy Creek	77, 78, 79, 80, 81, 82, 83 + MPF, GOP, HWP, TTP	5275	612	776	400	332	1946		7395		7027
Upper Muddy Creek	81,82,83 + MPF,GOP,HWP	2839	344	395	247	189	1322		4014		3860
Upper Muddy Creek Estuary surface deposition					59				59		59
Lower Muddy Creek	77,78,79,80 + TTP	2436	268	381	153	143	624		3381		3167
Lower Muddy Creek Estuary surface deposition					75				75		75

B) 2008 MEP Technical Memo Nitrogen Loads with updated Harwich water use and land use for Round Cove and Muddy Creek

		Pleasant Bay N Loads by Input (kg/yr):							Present N Loads		
Name	Watershed ID#	Wastewater	Fertilizers	Impervious Surfaces	Water Body Surface Area	"Natural" Surfaces	Buildout	% of Pond Outflow	UnAtten N Load	Atten %	Atten N Load
Round Cove	61,62 + MP	1884	175	162	77	53	263		2350		2341
Round Cove Estuary surface deposition					62				62		62
Muddy Creek	77, 78, 79, 80, 81, 82, 83 + MPF, GOP, HWP, TTP	7321	685	781	398	331	2235		9516		9086
Upper Muddy Creek	81,82,83 + MPF,GOP,HWP	4088	351	402	245	189	1543		5276		5066
Upper Muddy Creek Estuary surface deposition					59				59		59
Lower Muddy Creek	77,78,79,80 + TTP	3233	333	379	153	143	692		4241		4020
Lower Muddy Creek Estuary surface deposition					75				75		75

Table 2. Nitrogen loads (attenuated) under existing conditions for Harwich subestuaries of the Pleasant Bay system. Existing nitrogen loads for the watersheds to Round Cove and Muddy Creek are compared for the scenario discussed in this Technical Memo and the MEP report (Howes, *et al*., 2006). The requested scenario includes the incorporation of revised information gathered in Harwich into the 2006 MEP Linked Models for Pleasant Bay including: 1) average Harwich water use based on 2004 to 2007 data, 2) updated Harwich land use coverages from 2006, and 3) updated nitrogen attenuation from the 2008 SMAST assessment of Muddy Creek (White, *et al*., 2008). All values have been rounded.

Sub-embayment	Revised Harwich scenario				MEP Report				% change
	Attenuated watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)	Total Load (kg/d)	Attenuated watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)	Total Load (kg/d)	Total Load
Round Cove	6.24	0.17	8.42	14.83	4.23	0.17	8.42	12.82	+16%
Muddy Creek - upper	5.85	0.16	-0.64	5.37	9.98	0.16	4.56	14.70	-63%
Muddy Creek - lower	10.74	0.21	5.87	16.82	8.48	0.21	-1.23	7.46	+125%
Muddy Creek - total	16.59	0.37	5.23	22.19	18.46	0.37	3.33	22.16	0%

Table 3. Comparison of sub-embayment watershed ***septic loads*** (attenuated) used for modeling of present and threshold loading scenarios for Harwich subestuaries in the current requested scenario. These loads do not include direct atmospheric deposition (onto the sub-embayment surface), benthic flux, runoff, or fertilizer loading terms. All values have been rounded.

Sub-embayment	Revised Harwich scenario			MEP Report			change		
	Attenuated Septic load (kg/day)	Threshold septic load (kg/day)	septic load reduction to attain threshold % change	Attenuated Septic load (kg/day)	Threshold septic load (kg/day)	septic load reduction to attain threshold % change	Attenuated Septic load (kg/day)	Threshold septic load (kg/day)	septic load reduction to attain threshold % change
Round Cove	5.18	1.865	-64%	3.16	1.897	-40%	+2.02	-0.03	-24%
Muddy Creek - upper	4.72	1.603	-66%	7.16	1.789	-75%	-4.13	-1.79	+9%
Muddy Creek - lower	8.6	0	-100%	6.34	0	-100%	+2.26	0	0%

Table 4. Comparison of sub-embayment ***total watershed loads*** (attenuated, including septic, runoff, and fertilizer) used for modeling of present and threshold loading scenarios for Harwich subestuaries in the current Harwich-requested scenario and the 2006 MEP Technical Report. These loads do not include direct atmospheric deposition (onto the sub-embayment surface) or benthic flux loading terms. All values have been rounded.

Sub-embayment	Revised Harwich scenario			MEP Report			change		
	Attenuated total load (kg/day)	Threshold total load (kg/day)	load reduction to attain threshold % change	Attenuated total load (kg/day)	Threshold total load (kg/day)	load reduction to attain threshold % change	Attenuated total load (kg/day)	Threshold total load (kg/day)	load reduction to attain threshold % change
Round Cove	6.24	2.93	-53%	4.23	2.96	-30%	+2.019	-0.03	-23%
Muddy Creek - upper	5.85	2.82	-52%	9.98	4.61	-54%	-4.134	-1.79	+2%
Muddy Creek - lower	10.74	2.14	-80%	8.48	2.14	-75%	+2.26	0	-5%

Table 5. Threshold sub-embayment loads used for bioactive nitrogen (DIN+PON) modeling of the Harwich subestuaries in the current Harwich-requested scenario and the 2006 MEP Technical Report, with threshold loads for total attenuated watershed N loads, atmospheric N loads, and benthic flux. All values have been rounded.

Sub-embayment	Revised Harwich scenario				MEP Report				% change
	Attenuated watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)	Total Load (kg/d)	Attenuated watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)	Total Load (kg/d)	Attenuated Watershed load (kg/d)
Round Cove	2.93	0.17	5.59	8.69	2.96	0.17	6.74	9.87	-1%
Muddy Creek - upper	2.82	0.16	-0.37	2.61	4.61	0.16	2.7	7.47	-40%
Muddy Creek - lower	2.14	0.21	2.92	5.27	2.14	0.21	-0.71	1.64	0%
Muddy Creek - total	4.96	0.37	2.55	7.88	6.75	0.37	1.99	9.11	-27%