Shoreline Erosion and Chesapeake Bay Water Quality
A Scientific Evaluation of Prediction Uncertainty, Potential for Improvement, and Management Implications

Introduction –

In accordance with the Chesapeake 2000 Agreement, allocations of sediment and nutrient reductions for the Chesapeake Bay watershed are to be established by April 2003. The goal is to significantly improve water quality and clarity in the Bay and its tributaries by 2010 in order to remove them from the EPA Impaired Waters list. However, baseline decisions must be made sooner to allow for appropriate discussion. The Chesapeake Bay Program (CBP) asked its Scientific and Technical Advisory Committee (STAC) in December of 2002 to evaluate the scientific basis of selected nutrient and sediment allocation decisions. STAC decided that two sediment-related issues would benefit from quick technical review: the potential for shoreline erosion reductions to achieve improvements in water clarity and dissolved oxygen, and evaluating the effectiveness of shoreline vs. watershed reductions of sediment for improving Bay water clarity over the time frame of interest. This document primarily addresses shoreline erosion, but contains some recommendations relating to the relative influences of shoreline vs. watershed sediment sources because the two issues are interrelated. Additional information on the relative influences of different sediment sources will also be contained in the forthcoming report of the CBP Sediment Workgroup.

STAC members Scott Phillips and Larry Sanford, working with Kevin Sellner and the Chesapeake Research Consortium, organized a meeting in Annapolis, MD on January 9, 2003 to address shoreline erosion and its connections to water clarity and quality. The 24 participants included STAC scientists, external experts, and CBP and state management representatives. The goals of the meeting were: to evaluate uncertainties in the model projections being used to develop shoreline erosion allocations; to suggest specific areas for future work to improve the projections and reduce the uncertainties; to discuss implications for the allocation process; and to produce a brief written summary of findings and recommendations. The meeting was not designed to criticize the Bay WQ model or allocation process, nor to discuss allocation quantities or distributions.

Meeting synopsis -

During a brief introduction, Sanford explained that a fully functioning CB sediment transport model with process-based shoreline erosion parameterizations does not exist, though it is being planned. Basic empirical representations of shoreline sediment inputs and sediment transport have been added to the existing WQ model in order to achieve reasonable suspended solids predictions. Model simulations based on these parameterizations have indicated that decreases in sediment inputs from the Bay's shoreline might result in significant improvements in shallow water clarity and deep water dissolved oxygen levels. These projections have lead to suggestions that some mix of shoreline erosion control and nutrient input control might be more effective than nutrient control alone.

The group then heard from Carl Cerco of the US Army Corps of Engineers Waterways Experiments Station about implementations of shoreline erosion, fine sediment transport, water clarity calculation, and microphytobenthos production in the present Chesapeake Bay Program Water Quality Model. These processes are directly involved in predictions of water clarity and dissolved oxygen changes in response to shoreline erosion controls. Cerco stated that a constant (in both space and time) shoreline sediment source is input into each nearshore model cell. A value of 5.7 kg/m/day (with 68% silt) is used to represent a long-term average of shoreline erosion. The average daily value for bank solids used for the model was based on findings of Ibison (1992). The Ibison study reported shoreline erosion values of 11.4 kg/m/d with 61% silt. Lower values were needed in the WQ model to achieve a reasonable calibration with observed total suspended solids (TSS) data collected in the mainstem and mid-channel locations of the tidal tributaries. The justification for using lower values in the WQ model is the fact that the Ibison study focused on areas of high erosion and therefore did not represent "average" conditions needed for model.

The introduced sediment is assigned a settling speed in the water column of 1 m/day for TSS <100 mg/l and 5 m/day for TSS>100 mg/l. The net settling rate across the sediment-water interface is reduced to 0.1 m/day for TSS <100 mg/l and 5 m/day for TSS>100 mg/l to mimic the effects of resuspension. The higher settling speeds for TSS>100 mg/l allow for rapid sedimentation during storm events. Water clarity is then calculated using a semi-empirical function of TSS (total suspended solids), including organic as well as inorganic components. Microphytobenthos are modeled as a thin photosynthetic layer at the sediment-water interface that can intercept and/or alter nutrient and chemical fluxes, depending strongly on the amount of light reaching the sediment surface. Shoreline sediment inputs go directly into suspension in the nearshore model cells. While in suspension, these sediments directly impact water clarity near the shoreline and indirectly control the photosynthetic activity of the microphytobenthos, with consequent impacts on sediment nutrient uptake and oxygen production. The microphytobenthos consume nutrients and decrease the nutrient supply available to other algae like phytoplankton, thereby yielding less detrital biomass to be decomposed in deeper parts of the Bay. The microphytobenthos produce oxygen locally as well.

Bob Koroncai, the chair of the CBP Allocations Team, followed with a presentation on the projected magnitude of dissolved oxygen and water clarity improvement for different nutrient/sediment allocation scenarios. He noted that the model predicted dissolved oxygen responded most strongly to nutrient reductions, with a plausible reduction in shoreline erosion of 20% improving dissolved oxygen by an additional 10% in the most impacted segment, CB4. The same reduction in shoreline inputs resulted in much more significant projected improvements in nearshore water clarity, however. Koroncai described three scenarios for deciding on shoreline erosion control allocations, ranging from complete reliance on model projections to use of the model projections as only one of many sources of information to set general guidelines, with a local focus on water clarity in particular regions of concern for reestablishing SAV. He confirmed the possibility that shoreline erosion control allocations might be used to slightly relax nutrient control allocations.

The morning session ended with presentations by Tom Cronin and Jeff Halka, who represented the CBP Sediment Workgroup's findings on shoreline erosion and summarized the current state of shoreline erosion understanding and research in the Bay. They pointed out the large spatial variability of shoreline erosion in the Bay system, its increased significance as a sediment source below the turbidity maxima that characterize the upper reaches of the Bay and its tributaries, and the additional source of sediment represented by erosion of nearshore subaqueous bottom sediments to substantially greater depth after erosion of the fastland (above mean water level). Fastland erosion is estimated to account for about 1/3 and near-shore erosion about 2/3 of the total erosion occurring in shoreline areas. The Sediment Workgroup report will be released by the end of January, and will contain a thorough summary of this and other sediment-related issues.

After lunch, the entire group discussed general issues related to shoreline erosion, suspended sediment, influences on water clarity and quality, incorporation of sediment processes in the WQ model, and provision of information for management decision-making needs. Management representatives in general expressed a need for more information on sediment inputs and processes, information on potential shoreline erosion control measures, realistic constraints on controllability, and more guidance for making sediment-related management decisions. There was general consensus that the current implementations of shoreline inputs and suspended sediment processes in the WQ model were in need of improvement; i.e., that they were artificial (though reasonable) fixes to a modeling framework that was not designed to address sediment questions. The lack of interactions between biology and suspended sediment was also noted, in particular the potential for biological processes to influence sediment settling and resuspension. Rich Batiuk summarized the principal management questions as follows:

1. Is the current model over- or under-estimating shoreline sediment inputs?
2. Is the current model over- or under-estimating the influences of sediment inputs on water clarity and quality?
    2a. How can we better define the links between sediment inputs and water clarity and quality?
3. What is the appropriate scale for shoreline sediment input reductions? Is it a model cell, an entire region (or tributary), specific priority areas, or …?
4. What are the implications of these uncertainties for the sediment allocation process?

After the general discussion, most of the management representatives left, after which the scientific and technical representatives discussed science questions, prediction uncertainties, and recommendations for shoreline sediment input allocations.

<u>Recommendations -</u>

During the afternoon scientific/technical discussion, the group formulated the following responses to the principal management questions posed above:

<u>1. Is the current model over- or under-estimating shoreline sediment inputs?</u> Shoreline erosion in the Chesapeake Bay and its tidal tributaries is a very complex process. Having only one value for the shoreline erosion in the WQ model does not take into account temporal variability, spatial variability, bank composition variability, degree of existing protection, fast land vs. nearshore subaqueous erosion, or the potential for acceleration of sea level rise. ***Given these multiple factors, the average rate of sediment input from***

shoreline erosion is probably being underestimated in the current CBP WQ model. The values used to represent shoreline erosion in the WQ model and Ibison (1992) only represent the fastland component of erosion. Therefore the larger subaqueous nearshore erosion component is not accounted for in the current version of the WQ model. ***In addition, the use of a spatially and temporally averaged shoreline erosion rate is of limited utility for investigating nearshore water clarity and water quality issues that are inherently site specific and seasonally varying.***

<u>2. Is the current model over- or under-estimating the influences of sediment inputs on water clarity and quality?</u> The factors affecting shallow water clarity are still not completely understood in the Bay and its tidal tributaries. Other than a few localized studies, adequate data have not been collected in shallow water (< 2 meters) to identify the factors affecting light; many more field measurements of TSS and turbidity levels are needed. These measurements should include data on TSS composition and optical characteristics, and where possible frequently sampled time series should be collected. Previous studies have indicated that inorganic TSS is the principle cause of degraded nearshore water clarity. However, several participants felt that the influences of biological processes on both water clarity and total light reaching SAV leaves were not adequately represented in the model, especially potential nonlinear interactions. General agreement on this topic was not reached; it should be addressed more thoroughly.

Most importantly, however, the group agreed that ***links between shoreline sediment loads and nearshore TSS are inadequately represented in the present WQ model.*** Because of the low water column settling rates and even lower net sediment deposition rates required to compensate for the lack of resuspension processes in the model, modeled shoreline sediment loads remain in suspension for unrealistically long times. In reality, it is quite likely that shoreline erosion events lead to very high TSS for relatively brief times. This sediment is then deposited on the bottom where it is subject to episodic resuspension by waves and nearshore currents, but rapid settling after each episode again leaves the water column relatively clear. ***Thus, while average shoreline sediment inputs are likely underestimated, average nearshore TSS levels are likely overestimated. This leads to likely over-estimation of the influence of shoreline sediment inputs on water clarity.*** This assessment must be regarded as tentative, however; there is a critical need for more data in nearshore environments before a final evaluation can be made.

There was general consensus that the mechanisms linking shoreline erosion reduction to improvements in deep water dissolved oxygen through improved water clarity and increased shallow water microphytobenthos production were plausible, but unproven. There are several sources of uncertainty. First, the proposed link depends largely on the relationship between shoreline erosion and water clarity, which is likely overstated. Second, the present model does not allow for microphytobenthos erosion and transport to deeper waters, which is quite possible and would lead to increased deep water oxygen demand. Finally, for this link to be meaningful from a management perspective, the magnitude of shoreline sediment reductions needed to achieve significant dissolved oxygen improvement need to be practical. The CBP has done runs showing significant dissolved oxygen improvement with reductions of between 30 and 100% of shoreline sediment loads. The group felt that this much shoreline erosion reduction was more than could be practically achieved, given current efficiencies of shoreline protection (especially shoreline hardening). ***Thus, shoreline erosion controls should not be considered at this time for setting allocations intended to improve deep water dissolved oxygen.***

3. What is the appropriate scale for shoreline sediment input reductions? Areas above the Estuarine Turbidity Maxima (ETM) in the mainstem Bay and most tributaries are more influenced by watershed sources and areas below the ETM are more influenced by shoreline erosion. Marine sources may play an important role in the lower Bay, as well. In many places, shoreline erosion and its influences on water quality are highly localized. ***Therefore more detailed local targeting of the shoreline erosion allocations in priority areas for SAV below the ETM would be ideal. However, because the WQ model only has one value for shoreline inputs it should not be used to assign sediment allocations at this more detailed scale.*** Other data should be utilized to help with more detailed local targeting of shoreline sediment allocations.

4. What are the implications of the uncertainties discussed here for the sediment allocation process? The CBP is currently considering three options for sediment allocations: 1) Load-based/Segment Specific allocations based entirely on model projections; 2) Load-based regional allocations informed by the model projections, with specific goals set for water clarity in priority areas; and 3) Area specific allocations based on SAV water clarity requirements and existing conditions, with relatively little input from the model projections.

The group consensus was that option 1 should not be pursued. There is too much variability in shoreline erosion that is not represented in the WQ model to use this option. The group felt ***consideration should be given to some mix of options 2 and 3***, although no consensus on one or the other was reached. Instead***, a general approach was suggested as follows:***

a. ***Determine the nutrient allocations needed to achieve dissolved oxygen goals in priority segments of the Bay.***
b. ***Then consider sediment allocations in SAV-priority areas to achieve water clarity goals that are not met by the nutrient allocations.***

In addition to addressing these specific management questions, the group made some general recommendations for sediment allocations, both watershed and shoreline:

a. Consider dividing dominant sediment allocations between tidal fresh zones above ETM that are more influenced by watershed sources, and areas below ETM that are more influenced by shoreline erosion. Each of these areas might be further subdivided based on SAV priority areas as suggested in CBP options 2 and 3 above.
b. Shoreline erosion has a predominantly local impact on water clarity, but specific numerical goals for local shoreline load allocations probably cannot be set at this time due to a lack of data and management tools. The CBP should consider structuring the allocations so they can be refined as more information and improved management tools become available.

c. Allocations for watershed sources need to consider the long transport time (decades and more) of sediment from the watershed to the Bay and its tidal tributaries. Therefore, watershed allocations meant to improve Bay water clarity by 2010 should be targeted at watershed areas with high sediment yields that are closest to the Bay and its tidal tributaries. However, targeting sediment reductions in all regions of the Bay watershed will eventually be beneficial for both the watershed and the Bay, and should still be pursued.
d. Allocations for shoreline erosion reduction need to consider potential adverse impacts of some shoreline erosion control methods on nearshore habitat . For example, dunes and beaches are critical habitats for a diverse array of estuarine flora and fauna. In some locations, local reduction of shoreline erosion may accelerate erosion of the down-drift coast with unintended negative consequences. Hard armoring of the shoreline should be avoided where possible, emphasizing instead soft methods such as establishment of SAV beds, oyster bars, or fringing marshes, or construction of offshore breakwaters. Limiting shoreline erosion controls to preserve nearshore habitat may further reduce overall maximum achievable shoreline sediment reductions below the approximately 30% corresponding to 100% armoring with 30% efficiency.
e. It is also important to note the necessary and beneficial functions of fine sediments within estuaries, particularly with regard to marshes. Sediment is critical for maintaining the elevations of tidal wetlands as sea level rises. An important source of sediment to marshes is overbank flooding, which delivers suspended fine sediments to the marsh substrate. Complete elimination of the fine sediment sources that feed marshes might further accelerate losses of this critical estuarine habitat in the Bay system.
f. Resuspension of sediment by wave energy in shallow nearshore waters is an integral part of variability in nearshore water clarity. This process is not currently addressed in the WQ model, but it should be included in the planned future sediment transport enhancements. Allocations for shoreline erosion reduction should be targeted towards BMP's addressing reduction of wave energy in shallow areas to attempt to reduce sediment resuspension.

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