

Science and Site 104

A Perspective of Scientists from the
University of Maryland Center for Environmental Science

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Summary

Scientists from the University of Maryland Center for Environmental Science have evaluated the scientific understanding and uncertainty related to five issues regarding the environmental effects of placement of dredged sediments at Site 104, at the head of the deep, natural channel of the Chesapeake Bay. This assessment was based on reviews of relevant studies and impact statements as well as on the scientists' extensive knowledge and experience concerning the Chesapeake Bay ecosystem. The results of the assessment are cast as a series of predictions, each of which is assigned a level of uncertainty: low—confident prediction of an outcome; medium—prediction of a likely outcome, but with some chance of surprise; and high—informed prediction with advised caution.

Release of nutrients. A small fraction of the phosphorus and a more substantial portion of nitrogen contained in the dredged sediments would be released during or after placement. Although not strictly “new” inputs, nitrogen releases would add to the already excessive loading in the upper Bay. This addition would be less than one percent of the nitrogen inputs from land and the atmosphere during a 5 year period. The effects of this reinjection of buried nutrients would not be perceptible in terms of algal biomass or hypoxia in the upper Bay and could only locally stimulate algal growth during the first few weeks of the proposed annual dredging period. These predictions are made with a low level of uncertainty.

Transport and fate of dredged sediments. The physical characteristics of the silty-clay bottom at Site 104 will not be appreciably changed (uncertainty low to moderate). Small amounts of the dredged sediments would inevitably be released during placement as plumes of suspended matter, which would dissipate or settle within hours with few effects (uncertainty low). After placement, a substantial majority of the sediments would permanently remain within the site boundaries, but there is moderate uncertainty regarding model predictions that only 6-12% would escape the site. Sediments eroded by tidal currents would mostly be redeposited along the deep channels of the Bay and not settle on sensitive shallow-water habitats (uncertainty low-moderate).

Effects of sediment contaminants. Because contaminant levels in the dredged sediments are similar to the present background levels for silty-clay in the Bay and are chemically bound to the sediments, no significant toxic effects of bioaccumulation would result from the resuspension of dredged sediments during placement (uncertainty low). After placement of dredged sediments, concentrations of toxic substances in the surface sediments at Site 104 will be essentially similar to those present now, although contaminants may become somewhat more bioavailable for a short period following placement. The uncertainty is moderate because the contaminant levels of surface sediments could be lowered as a result of covering of more contaminated sediments.

Effects on fish and shellfish. Some mortality of stationary or slow-moving fishes and crabs living at the bottom will occur when the dredged sediments are placed. Potential

impacts on sensitive fish early life stages would be avoided if placement is confined to October through March, as opposed to April 15. Uncertainty regarding these direct impacts is moderate, mainly with regard to the degree of impact on bottom-dwelling organisms. The elevated bottom (40 to 45 feet) would remain subject to seasonal hypoxia (highly stressful low dissolved oxygen conditions), although hypoxia would be more intermittent and less severe than at present. Any habitat improvement in terms of oxygen and bottom habitat quality should be considered modest, at most. Uncertainty is moderate; small improvements in dissolved oxygen could result in greater biological improvement. The depth reductions will reduce the amount of deep-water habitat that provides a warmer refuge for over-wintering white perch, striped bass and sturgeons. This will cause such species to aggregate more in the remaining deep-water refuges, potentially altering predator-prey interactions in the region. Uncertainty is high because of the paucity of scientific information on deep-water winter habitat use, but could be reduced by more in-depth analysis of effects on temperature.

Alternatives for sediment placement. All options for placement of dredged sediment have some potentially deleterious environmental consequences; without careful comparative analysis it cannot be concluded that placement of dredged sediments at Site 104 is inherently more deleterious than the alternatives. The very fine nature of the sediments provides some limits on the beneficial uses of these sediments, but their use in restoration and nourishment of tidal marshes that are degrading as a result of sea level rise present potentially beneficial long-term opportunities. If one is to manage the Chesapeake Bay as an ecosystem, offsetting mitigation of dredged sediment placement, for example urban nonpoint source controls and oyster reef restoration, should be considered. However, holistic consideration of alternatives and mitigation requires more effective application of scientific knowledge and capabilities than has been the case thus far. Attendant with the complexity of assessment of multiple options, mitigation and ecosystem management, uncertainty is judged to be moderate.

Based on these perspectives, the questions that merit greater attention deal with: the relative losses of nutrients (particularly nitrogen), sediments and contaminants among open-water, upland and island dredged sediment placement options; the dissolved oxygen conditions that would occur at the raised Bay bottom; and the long-term consequences of alterations of topography at Site 104 and the deep channel, particularly with regard to winter fish habitat. In the long-term, there is a need for comprehensive and scientifically grounded consideration of alternatives for dredged sediment placement, restoration goals and mitigation options.

These general assessments are offered to contribute to agency analysis and public understanding rather than as a definitive, quantitative analysis of impacts and alternatives. The University of Maryland Center for Environmental Science stands ready to apply its diverse scientific expertise in the continuing evaluation of the Site 104 option and in the development of long-range approaches to management of navigation channels. The Center's Integration and Application Network initiative will enhance its capabilities for truly transdisciplinary analysis and assessment.

Objectives

The proposal to place sediments dredged from navigation channels approaching Baltimore in an open water location in the deep natural channel of the Chesapeake Bay, called Site 104, has generated intense controversy. This controversy involves state and federal agencies, maritime commerce and fishing interests, conservation organizations, elected officials and the general public. Some of the concerns are related to the decision-making process, economic costs, and perceptions that “overboard disposal” is contrary to the substantial governmental, private and individual commitments to protect and restore the Chesapeake Bay. But, a substantial part of the controversy revolves around the scientific assessment of potential impacts on environmental quality and living resources provided in a Draft Environmental Impact Statement (DEIS) prepared by the U.S. Army Corps of Engineers Baltimore District and in various appendices and addenda to that DEIS. Interestingly, those on all sides of the debate are evoking the need to apply sound science in the important decisions facing the management of channel-dredging activities.

As a result of the concerns of other Federal agencies, public officials, and the general public, the Corps of Engineers has announced that it will revise the DEIS after additional consultation with agencies and stakeholders. As a contribution to this further discourse, the University of Maryland Center for Environmental Science (UMCES) is offering this initial, integrated appraisal of the potential impacts based on the scientific knowledge and interpretation of its faculty members most knowledgeable about the relevant subjects. The Center is in an authoritative position to provide this appraisal because of its history of successful research on many of the key environmental processes in question. Moreover, because of its legislative mandate “to develop and apply a predictive ecology for Maryland,” the Center has a responsibility to offer independent scientific assessments.

The scientists who contributed to this summary assessment are neither advocating nor opposing placement of dredged sediment placement at Site 104. We recognize that such decisions are most appropriately made based on public policy and economic considerations in addition to knowledge from environmental science. Rather, it is our goal to inform debate and policy development as objectively as we are able.

The Issues

As mentioned above there are various policy, process and economic issues that surround decisions regarding dredged sediment placement. Here, we focus only on the issues that revolve around scientific understanding and uncertainty. The most significant environmental effects of maintaining navigation channels probably result from the existence of the channels themselves. These artificial channels affect water circulation, the distribution of sediments and chemicals, and the ecology of the Bay. But we start with the assumption that our society is committed to maintaining maritime commerce into the Port of Baltimore. Given the inexorable tendency of the upper reaches of the Chesapeake Bay to fill up with sediments, this will require periodic removal of sediments

deposited to maintain dredged channels, regardless of whether channels are deepened. Therefore, the issue then becomes a question of how much (if any) of this dredged sediment should be placed at Site 104 and how much at other locations, be they open-water, confined upland, artificial island or in beneficial uses.

Written comments offered to the Baltimore District on the DEIS provide some basis for focusing on those concerns which science can address. Such concerns expressed by the U.S. Fish and Wildlife Service, the National Oceanic and Atmospheric Administration, Environmental Protection Agency, Congressman Wayne Gilchrest, Queen Anne's County, the Chesapeake Bay Foundation and Sierra Club can be grouped under five issues:

1. nutrient releases resulting from dredged sediment placement;
2. transport and fate of dredged sediment during and after placement;
3. effects of sediment contaminants;
4. effects on fish and shellfish; and
5. alternatives to dredged sediment placement at Site 104.

Our goal here, therefore, is to shed scientific light on these five issues in order to provide suggestions for the continuing environmental impact assessments of the Site 104 alternative and the long-term management of dredged channels in the upper Chesapeake Bay. But, first to set the stage we provide some thoughts about the role and nature of science.

Science, Uncertainty and Bias

Doubt is not a very agreeable condition, but certainty is absurd. Voltaire

As mentioned above, we recognize that scientific knowledge is but one consideration in environmental decision making. In the present case, those entrusted by society for making such difficult decisions may conclude that, even though the soundest science available indicates that the impacts of dredged sediment placement would be extremely small, Site 104 should not be used for reasons related to public concerns or policy consistency. On the other hand, those decision-makers may decide to use Site 104, even when scientific interpretation predicts that the impacts would be consequential, if the alternatives are deemed economically and environmentally less desirable.

We, like most scientists, are instinctively reluctant to draw definitive conclusions and make categorical statements, stereotypically asking more new questions than answering old ones. In this assessment we have challenged ourselves to draw conclusions based on existing knowledge as crisply as possible but also to indicate the level of uncertainty we assign to those conclusions. Although certain basic physical phenomena are so well known from experience or theory as to allow practically certain predictions, some level of uncertainty always exists regarding predictions about things as

complex as ecosystems, particularly ones as dynamic and variable as the Chesapeake Bay. Those seeking absolute certainty regarding the consequences of dredged sediment placement at Site 104 will be disappointed.

Scientists can contribute more effectively to public discourse and decision-making if they indicate the level of uncertainty associated with the outcomes they predict. Here we will attempt to do so, not formally as statistical probabilities, but in relative terms based on the completeness of evidence and our accumulated scientific knowledge and wisdom about the Bay ecosystem. We will indicate whether, in our judgement, a conclusion can be drawn with low, moderate or high level of uncertainty:

- Where uncertainty is judged to be **low**, we believe one could confidently predict an outcome and plan on that basis.
- Where uncertainty is judged to be **moderate**, we believe the predicted outcome is very likely based on the evidence and understanding, but there is some chance of surprises.
- Where uncertainty is **high**, an informed prediction can be made, but we advise considerable caution in relying on it.

Finally, we recognize that scientists too have their own values and social viewpoints. In this assessment, we have challenged each other to overcome biases to produce an objective evaluation. In this light, it should be stated that this assessment is internally motivated rather than requested or commissioned. A portion of the research of UMCES and several of the scientists contributing to this summary was supported by the Maryland Port Administration and Maryland Environmental Services for scientific studies of Site 104 or other dredging issues. It is reasonable to ask whether there is bias toward the interests of those sponsors. We have worked to guard against such bias because we recognize that in the long term, the success of the scientific enterprise within the Center depends on its reputation for excellence in science and its objectivity. We guard and advance this reputation assiduously. In any case, the funding received from the aforementioned agencies or the Corps of Engineers has constituted only about 1% of the external research support received by the Center over the last few years. On the other hand, the Center receives significant support from other federal agencies, including those that have voiced concerns about dredged sediment placement at Site 104 (Environmental Protection Agency, National Oceanic and Atmospheric Administration, and Department of the Interior together provide over half of the Center's external research support). Finally, we have gone to great lengths to avoid the use of value-laden terms and expressions. For example, we consistently refer to dredged "sediments" rather than the positive image of "material" or negative connotation of "spoil."

Scientific Assessment of the Issues

Nutrient Releases from Dredged Sediment Placement

Given the large commitment to reduce nutrient inputs into the Bay, will the disposal of dredged sediment release significant amounts of nutrients, thus degrading water quality (dissolved oxygen, water clarity, algal blooms) in the Bay in general or locally near Site 104?

Nutrient over-enrichment (eutrophication) is a major and pervasive factor in the degradation of the Bay ecosystem. Consequently, a central goal of the Chesapeake Bay Program is the reduction of controllable inputs of the major nutrients, nitrogen (N) and phosphorus (P), into the Bay by 40% by the year 2000. Some of the nutrients cycling through the ecosystem are deposited in bottom sediments of the Bay. A portion of these nutrients in the near-surface sediments is eventually released back into the water column, but part of the stored nutrients can be considered more-or-less permanently retained unless the sediments are disturbed. The dredging and placement of sediments from navigation channels inevitably result in the remobilization of some portion of these nutrients back into the water column, where they may stimulate the growth of phytoplankton, thereby contributing to turbidity and depletion of oxygen. The key scientific questions are (a) how much of these buried nutrients would return to the overlying waters; (b) is this return of nutrients significant or very small with respect to nutrients being added from land (point source discharges, nonpoint source runoff, and atmospheric deposition); and (c) would this release of nutrients, even if small in the context of the upper Bay region, cause localized impacts such as algal blooms.

UMCES scientists have measured the exchange of nutrients between the sediments and overlying waters at other sites of dredged sediment placement, e.g. Pooles Island; in navigation channels; and at Site 104. They have also conducted laboratory experiments to measure the potential release of nutrients from disturbed channel sediments. We can interpret these results in the context of two decades of research on nutrient recycling at the Bay bottom as well as the physical, biological and geochemical processes that control recycling in the water column and bottom sediments. Based on the specific results and general understanding of the processes involved, we draw the following conclusions about the nutrient releases and their consequences:

1. **A small fraction of the phosphorus in the dredged sediments would be returned to the water column** (uncertainty low). The sediments in the channels are geochemically “young” in that they are iron-rich and relatively low in sulfides. The oxidized iron in the sediments binds the phosphate, keeping it associated with the sediment particles as they are removed from the channel, transported, and placed at the disposal site. Although in the deeper parts of the Bay phosphate leaves the sediments during seasonal anoxia (absence of oxygen in bottom waters), the substantial majority of the phosphorus in sediments placed on the bottom at Site 104 would remain there.

It is the production of sulfide as a result of the decomposition of fresh organic matter rather than anoxia of overlying waters that releases the phosphate from near-surface sediments. The channel sediments to be dredged are not rich in fresh organic matter; but as such organic matter accumulates on the surface of sediments placed at Site 104 it would result in the return of only the phosphorus in the top few centimeters of the dredged sediment deposit.

2. **A more substantial portion of the nitrogen in the dredged sediment, potentially almost all of the dissolved inorganic nitrogen, would be returned to the water column** (uncertainty low). Dissolved forms of inorganic nitrogen in sediment pore waters (predominantly ammonium) are not as tightly bound chemically to the sediment particulates as is phosphate. Some of the nitrogen would be released during the dredging of sediments, some during placement, and some after placement. Higher than normal fluxes in nitrogen have been observed for several months after sediment placement at other sites. The estimates of nitrogen release provided in supplements to the DEIS that have drawn so much attention are an attempt to determine the maximum amount of release that is possible when sediments are vigorously mixed with Bay water. These conditions could possibly occur if the dredged sediments were placed near the bottom hydraulically. In that process the sediments would be mixed with larger volumes of water to facilitate transport. However, the losses would be less if the dredged sediment were released from scows at the surface in a relatively cohesive mass. Thus, the estimate of 0.11 pounds of nitrogen per cubic yard (320 g/m^3) used for losses associated with hydraulic placement at Site 104 should be considered an upper estimate. Because of the different assumptions involved, comparisons of this estimate with those for nitrogen losses from confined placement sites should be made with great caution. The losses from the confined site at Hart-Miller Island were made by comparing concentrations in overflows with the volumes of sediments placed. This estimate does not include all possible escape routes for nitrogen and, thus, should be regarded as a minimum estimate.
3. **In any given year, the amount of nitrogen and phosphorus that could be returned to the water column of the upper Chesapeake Bay as a result of dredging and sediment placement at Site 104 would be substantially less than one percent of new inputs of those nutrients from land and the atmosphere** (uncertainty: low). Comparison of the nutrients remobilized to those newly input from other sources is appropriate and not trivial. The most dramatic manifestation of eutrophication in the upper Bay is the seasonal depletion of dissolved oxygen in deeper waters. This is the result of widely distributed nutrient sources, including the Susquehanna River and many other point and nonpoint sources. Put another way, the mainstem Chesapeake Bay is a large and biologically active mixing bowl of recycling nutrients, organic matter and dissolved oxygen. Although the nutrient releases associated with the dredging and sediment placement would add incrementally to the pool of available nutrients and increase slightly the production of organic matter in surface waters, the effect on dissolved oxygen conditions in the mixing bowl would be so small as to be undetectable.

Notwithstanding, this relatively minor effect on oxygen condition, the challenge of reduction of eutrophication requires that efforts be made to control virtually all sources of nutrient inputs to the Bay. Every little bit helps. Although nutrients released by dredging and placement do not represent new inputs into the Bay, this does not mean that we should not be concerned about human activities that remobilize nutrient “sinks,” such as the nutrients buried in bottom sediments. Reversal of eutrophication in the Bay requires reduction of sources and more effective trapping of the remaining nutrients in sinks, including forests, riparian zones, wetlands and bottom sediments. In that context, there are many activities that resuspend Chesapeake Bay sediments that deserve attention for control or mitigation. These include, in addition to channel dredging, fossil shell dredging, hydraulic clam dredging, and prop and wake wash from ships and smaller vessels.

- 4. Localized stimulation of algal growth from nutrient releases during low temperature periods would not produce harmful or nuisance blooms, but some stimulation of algae could occur as a result of dredged sediment placement in late fall** (uncertainty low). Although the amount of nitrogen released from dredging and placement is small in comparison to other sources in the upper Bay as a whole, the amount that could be released at a specific location in a given week or year is large relative to the nitrogen released from point source discharges in the region. However, during the period in which placement of dredged sediment would be restricted (15 October-April 15), nitrogen limits (or co-limits with phosphorus) phytoplankton growth only into December, when low temperatures and deep mixing usually result in light limitation in this part of the Bay. Phosphorus limitation begins in March and continues at least until mid-May. Thus any local impact on algal growth would be limited to the late fall period (due to nitrogen releases) and the early spring period (due to the much more limited phosphorus releases). During the winter, under light limited conditions, any dissolved nitrogen and phosphorus released would be dispersed and added to the larger pool available to support spring and summer phytoplankton growth, particularly down the Bay.

There is also no reason to expect that localized releases of nutrients would stimulate the growth of *Pfiesteria*-like dinoflagellates or their metamorphosis into toxic forms, as suggested in some comments. All evidence indicates that *Pfiesteria* resides in the shallow waters of tidal rivers and creeks and not in the open Bay, where the nutrient concentrations may be locally elevated by placement of dredged sediment.

Transport and Fate of Dredged Sediments

To what degree will the sediments placed at the site remain there or be transported away, either during disposal or over the long-term? Could these sediments smother oyster reefs or submerged aquatic vegetation?

Increases in suspended sediments and the deposition of sediments on sensitive bottom habitats such as oyster bars and submersed vegetation contribute to the degradation of the Chesapeake Bay ecosystem. Redistribution of large volumes of

sediments dredged from navigation channels to open water sites or semi-contained sites, including those intended for habitat improvement, adds to the mobile sediment pool, either through losses during dredging, losses during placement, or subsequent erosion after placement. Key scientific questions are (a) how would the placement of sediments alter the habitats at the placement site; (b) what would be the effects of the suspended sediment plume that is released during placement; (c) how much of the placed sediment would be eroded away by currents and waves; (d) where would this sediment eventually end up; and (e) might these escaped sediments be deposited on biologically active substrates that provide important habitat such as oyster reefs and submersed vegetation?

1. **The physical properties of surface sediments as Site 104 will not be changed by placement of dredged channel sediments** (uncertainty low-moderate). The bottom sediments both in the channels to be dredged and at Site 104 are very fine, predominantly silts and clays. The sediments from both sources have very high water content and, once settled, similar susceptibility to erosion by bottom currents. They would provide similar habitat conditions for colonizing bottom-dwelling (benthic) organisms. As mentioned above, the channel sediments are not as rich in fresh organic matter or sulfides (compounds that produce a rotten egg odor, may inhibit some benthic organisms, and greatly affect sediment chemistry) as the sediments at Site 104. However, fresh organic matter and sulfides would build up in the top several centimeters of these sediments within a few years after placement at Site 104 as organic material produced by plankton in the water column is deposited. The uncertainties associated with this prediction relate to unknowns regarding the exact nature of the dredged sediments (e.g. they may include older, coarser sediments) and the resulting topography of the deposits at Site 104.
2. **Sediments released during placement would produce a localized and transient increase in suspended sediments with minor biological effects** (uncertainty low). Models developed by the Corps of Engineers based on observations of numerous open water sediment placements and theoretical physical considerations indicate that a small portion (4% or less) of the sediments placed at Site 104 remain in suspension as a turbid plume long enough to move outside the Site. Observations of sediment placement at the shallower Pooles Island site indicated that turbid plumes were not detectable beyond 0.7 (bottom-release scow) and 3 (continuous hydraulic discharge) kilometers (0.4 to 1.9 miles). Suspended solid concentrations returned to background levels within an hour of completion of placement. Although the locally substantial increase in suspended sediments could affect exposed planktonic organisms in some way, any effects would be geographically limited and very short-lived. If placement were limited to fall and winter quarters, as the DEIS indicates, potentially sensitive larval fish would not be exposed, though some larvae may be present during the last few weeks of the proposed mid-October to mid-April dredging period.
3. **After placement, the substantial majority of the sediments placed at Site 104, either by release from surface vessels or hydraulic discharge near the bottom, would remain within the site boundaries** (uncertainty moderate). The Corps of Engineers applied models to estimate how much of the sediment placed at Site 104

could be eroded and transported out of the boundaries of the site after initial deposition. These models relate the predicted erosional forces or shear stresses (mainly due to tidal and wind-forced currents) at the bottom to the erodibility of the sediments that would be dredged from the navigation channels. Changes in erodibility during the first 8 days after placement were measured in laboratory tests. The Corps estimated that during 5 years of placement 12.6% of the dredged sediment placed by surface release from vessels and 6.2% of the sediment placed by controlled hydraulic pipeline could be transported beyond the Site boundaries. The models and erodibility testing techniques used represent the best available operational technology, but they remain somewhat uncertain. In particular, the early behavior of sediments placed in the complex, spatially and temporally variable environment of Site 104 can only be approximated by laboratory experiments. Thus, the predicted amounts eroded immediately following placement must be regarded as reasonable estimates rather than definitive calculations. However, the Corps models also are based on the liberal assumption that all sediment eroded from the bottom will ultimately be deposited outside of the site boundaries. In reality some of the eroded sediment would be redeposited within the site or, after deposition nearby, return to the site on reversing tidal currents. Dredged sediments previously placed at the site have not by-and-large been eroded away (see below) but rather have been covered by new, naturally deposited sediments. This, coupled with the liberal model assumptions and the general knowledge that this region of the central Bay channel is filling in rather than scouring gives us the impression that the model predictions do not greatly underestimate the amount of sediment losses due to resuspension.

4. **The substantial majority of sediments escaping the site boundaries would be ultimately deposited in other deep-water portions of the Bay, posing little risk for sensitive shallow-water habitats** (uncertainty low-moderate). A great concern has been where the sediments lost during placement or subsequent resuspension would ultimately end up. Could they be deposited on sensitive oyster beds or submerged vegetation or move into nearby tidal rivers? Sediment released during placement operations settles very quickly (typically within the first hour) to within 1-2 m of the bottom. Because of the density stratification of the water column and the tendency of sediment particles to settle, the great majority of any resuspended dredged sediments would remain in the bottom layer of the water column and ultimately find their way to permanent depositional sites in the deep channels of the Bay. Density stratification and suspended sediment settling rates are the most important controls on the height of resuspension. Most resuspended sediments in Chesapeake Bay appear to settle rapidly [approximately 80 m/day (262 ft/day)], which means that they tend to be transported in relatively short hops and remain near the bottom. Sediment particles in organic-rich estuaries such as the Chesapeake settle far more rapidly than predicted from the theoretical settling velocities of individual sediment grains because they almost always exist as aggregates rather than individual grains.

Density stratification limits mixing between the upper and lower layers of the water column in Chesapeake Bay. Strong mixing accompanying major storm events might

temporarily mix resuspended sediments higher in the water column, and some fraction of those resuspended sediments might settle slowly enough to be carried into adjacent shallow water habitats. But, it is likely that this would be a very small percentage and that it would not significantly increase background concentrations of suspended sediments in those areas.

Previous studies in the vicinity of Site 104 largely support conclusions about limited space and time scales of sediment transport following placement. However, they also reinforce uncertainties about detailed estimates of erosion and transport in the first few days following placement. The most relevant of these studies was a monitoring effort carried out during 1975 surrounding a limited placement of dredged sediments from Baltimore Harbor approach channels at Site 104. This study found that excess turbidity associated with the sediment plume descending from the barge was dissipated to background levels within approximately one hour, except for a layer of more turbid water that remained in suspension for at least 2 hours within 1 m (3 ft) of the bottom. There was no evidence of additional sediment deposition on adjacent oyster bars, no detectable shellfish mortality away from the placement site, and no detectable uptake of contaminants by shellfish. Bathymetric surveys before and after placement, along with an extensive sediment coring effort, indicated that 60-70% of the sediments reported to have been dredged were present on the bottom at the Site 104 after placement operations ceased. There was no detectable change in sediment volume in the following 8 months.

The fate of the remaining 30-40% of the dredged sediments is uncertain. It is not known, for example, what fraction of this material was actually placed at Site 104 versus escaping during the dredging process (note that the hopper dredging techniques used in 1975 were different from the techniques now proposed). It is also likely that some fraction of the sediment placed on the bottom was eroded and dispersed in the first few days, but the magnitude of this fraction and its fate were not determined. The bathymetric surveys also had a significant, but unspecified, margin of error.

Another relevant study was conducted in the Chester River in 1972. It concluded that the upper Chesapeake Bay (ultimately the Susquehanna River) was the most likely source for the fine sediments accumulating on the bottom in deep water inside the mouth of the Chester River. This conclusion is consistent with the estuarine circulation of the lower Chester, which results in an inflow of near bottom waters under most circumstances. Water from the deep central channel of the Bay has been shown to be the source for this saline inflow into the Chester. However, it would be a mistake to conclude from these studies that sediments from the deep trough and Site 104 are the primary source for lower Chester River sediments, since the transport of sediment particles is dominated by episodic events rather than the normal tidal exchanges of water. Studies have also observed that there is notably less tidal resuspension of in-place sediments in the deep Bay channel than would be expected from theory. Thus erosion and transport of dredged sediments placed in this area would depend critically on processes of compaction, consolidation, cohesion, and

armorings occurring within the first few days to weeks after placement, after which the sediments would become quite stable.

Effects of Sediment Contaminants

Will the disposition of dredged sediment increase the exposure of Bay organisms to potentially harmful chemical contaminants, such as trace metals?

The evaluation of the potential for release of potentially toxic contaminants is based on the information and conclusions concerning the fate of the sediment itself (see above) and knowledge of the chemical constituents, their concentrations and potential to enter solution. Although the concentrations of contaminants have been measured in sediments from channels to be dredged, the rate of contaminant release from sediments suspended in the process of dredging or placement is not well known for Chesapeake Bay sediments. Sediments are the main repository for organic and metal contaminants in the Bay. The concentration of metals and organic contaminants in sediments is often strongly related to sediment characteristics such as organic (organics and some metals), iron (metals) and sulfide content (metals). Given the relatively low organic and sulfide content of the proposed dredged sediments, it is likely that these sediments do not contain contaminant levels elevated above average Chesapeake Bay values and the reported analyses of these contaminants seem to bear this out. Based on this knowledge and the results of studies in other estuarine systems, the relative impact of sediment placement at Site 104 is assessed.

The over-riding concern is that exposure of estuarine organisms to suspended or bottom sediments may induce lethal or sublethal effects. Very high levels of these sediment-associated contaminants, including trace metals and organic compounds, are found where there are local sources of these contaminants, such as in industrialized harbors. This has led to procedures for chemical analyses and toxicity testing of dredged sediments in order to assess the risks posed by dredging and disposal. Sediments deemed “contaminated” according to these standards may not be placed at open water sites but must be placed in confined disposal sites. The sediments in the Baltimore approach channels do not have the high concentrations of chemical contaminants found in harbor sediments. Furthermore, they would be subjected to testing and comparison to standards for open water placement. These sediments do, however, contain small concentrations of manufactured organic chemicals, their by-products and naturally occurring trace metals at concentrations higher than those characteristic of Bay sediments deposited before European colonization. Key scientific issues are (a) would potentially harmful concentrations be released in the water column during dredging and placement; (b) would the bottom sediments at Site 104 after dredged sediment deposition pose a greater or lesser risk of toxicity to bottom-dwelling organisms; and (c) would contaminants in the redistributed sediments become more or less bioavailable?

1. **No significant toxic effects or bioaccumulation would result from the resuspension of sediments during placement** (uncertainty: low) As discussed above some loss of suspended sediments during placement is unavoidable, although

the turbid plumes would be very limited in size and duration. Even with controlled hydraulic placement there will be some turbid plume release, contrary to the assumption of the DEIS that there would be no losses to the water column. Because potentially toxic contaminants, such as trace metals, in the dredged sediments generally tend to be tightly bound to sediment particles, little of these substances would be released into solution. One metal of concern is copper (Cu) because the concentrations of Cu in the waters of the saline portions of the Chesapeake Bay are already near regulatory limits. Additionally, Cu is relatively weakly bound to sediment compared to other metals and there is, therefore, the possibility of its release during placement. However, any increased exposure to toxic contaminants to planktonic organisms or fish resulting from higher concentrations of dissolved or suspended contaminants would be acute (lasting minutes to hours) rather than chronic (long-term).

It is important that sediments actually dredged from the channels be tested regularly by analysis of elutriates to screen for the inclusion of any unusually contaminated sediment sources that may release unexpected amounts of contaminants. Based on screening protocols, potential effects of contaminants released during resuspension could be tested using laboratory-scale studies and bioassays.

2. **Concentrations of toxic substances in the dredged sediment are essentially similar to those in surface sediments at Site 104. Although some change in their bioavailability may occur with placement, these conditions would shortly return to those now existing at Site 104** (uncertainty: moderate). The concentrations of organic and trace metals in channel sediments and surface sediments at Site 104 are not remarkably different, although there may be some local patches of more highly contaminated sediments at Site 104. The average concentrations of some trace metals were found to be lower in channel sediments than at Site 104, but the patterns cannot be characterized as “markedly lower.” The placement of the dredged sediment will add to the water content of sediments and disturb existing geochemical gradients in the sediments, potentially making these contaminants more biologically available in the short term. However, with the stabilization of the sediments and deposition of fresh organic matter and generation of sulfides in near-surface sediments the conditions will eventually return to those presently existing at Site 104. We are not convinced that any improvement in surface sediment quality or significant capping of more highly contaminated sediments would result.

Effects on Fish and Shellfish

How will fish and shellfish populations be affected by dredged sediment placement (suspended sediments or burial) and long-term habitat changes? Will 104 Site be improved or degraded as a habitat for Bay organisms?

The potential for short and long-term effects of dredged material placement at Site 104 on fish and shellfish resources is of central concern. In the short term, the sediment placement itself could affect fish and shellfish populations either as result of exposure to

high suspended sediment concentrations, burial (e.g. hibernating blue crabs) or off-site sedimentation (oysters). Even more concern has been focused on the long-term implications of the changes in the habitat conditions at Site 104 on these resources. Presently, the bottom at Site 104 is 13-24 m (42-74ft) deep. The dissolved oxygen concentrations at these depths are reduced to near zero on a seasonal basis (at least June through August). The DEIS concludes that the quality of the habitat would actually be improved as a result of raising the elevation of the bottom to a level at which there would be more dissolved oxygen and, thereby, greater access to the habitat and greater production of bottom-dwelling prey. On the other hand, others have expressed concern that the habitat would, in fact, be degraded either because of worsened sediment quality or the obliteration of topographic features that provide habitat complexity and refuge. They point out that the site lies within areas of the Bay designated as critical fish habitat, such that degradation of that habitat could affect fishery resources. Key scientific questions are (a) how would the dredged sediment placement activities affect fish and shellfish populations regionally; (b) would dissolved oxygen conditions at the bottom after the completion of sediment placement allow more food resources and greater use of the habitat by fish and crabs; and (c) what would be the significance of any local impacts on fish and shellfish resources in the Bay.

1. **Some mortality of adult or juvenile fish and crabs living near or burrowing in the bottom would occur; however if placement of dredged sediment is confined to mid-October through March, effects on sensitive larval life history stages would be substantially avoided** (uncertainty moderate). The massive deposition of large amounts of dredged sediment on the bottom would obviously pose a risk to organisms burrowing into the bottom or living near it. During the times of year in which placement is planned, mortalities of buried, overwintering blue crabs are distinctly possible. However, winter dredge surveys for blue crabs do not indicate that the abundance of crabs within Site 104 is unusually high. Other sedimentary benthic invertebrates may be similarly affected. Deaths of bottom-dwelling fishes (such as catfishes, eels and blennies) may also occur during placement. However, many of these species are highly motile and individuals would likely move away from the direct area of placement. In both cases, from a regional point of view, these mortalities would only affect a very small portion of the populations of these species. A potentially more serious concern is the effects of sediment placement, either through release of suspended sediments or sedimentation at the bottom, during the larval development period of species dependent on the upper Bay as a nursery area. For such species a substantial portion of the year class of the total Bay population would be potentially at risk. Although these nursery zones are generally north of Site 104, the extension of dredged sediment placement activities into April, as proposed, may encroach into a critical period for larval development. For example, were placement activities to impact negatively the light environment in which early life stages of fishes search for their planktonic prey, growth rates of the fish may be detrimentally affected. Accordingly, the later into the spring placement occurs, the greater the chance of negative impacts.

2. **After placement is completed the new bottom depths would remain subject to seasonal hypoxia, although it would be more intermittent and less severe. Consequently, any habitat improvement should be considered modest at best** (uncertainty moderate). The DEIS claims that significant improvement of the bottom habitat would occur as a result of the proposed dredged sediment placement at Site 104. The bottom will be elevated to a depth (40-45 ft or approximately 12-14 m) where oxygen is more available during the warmer months of the year. However, the abrupt decline in dissolved oxygen concentrations from the surface to the bottom in the vicinity of Site 104 typically takes place between 10 and 12 m. In other words, the newly configured bottom would still experience hypoxia (highly stressful concentrations of dissolved oxygen) substantially below 2 mg/L during the summer months (June through August). Because it would be shallower and closer to the abrupt vertical gradient, there may be more intermittent oxygenation of the bottom due to wind mixing and seiching (“sloshing”) of Bay waters and hypoxia may develop some days later and dissipate some days earlier, but any habitat improvements should be considered modest, at this point. It should be pointed out, however, that if oxygen conditions above the bottom are improved, the dredged sediments may provide a more effective sink for nitrogen and phosphorus than is the present situation at Site 104.

3. **Given the status of many fish populations and the overall degradation of their habitats, no habitats should be considered unimportant. Within the context of the entire Bay, however, the habitat at Site 104, although not essential to any population, may be an important winter thermal refuge for white perch, striped bass and sturgeons** (uncertainty high). Several of the comments have pointed out that Site 104 falls into areas designated as Essential Fish Habitat under the federal Fishery Management and Conservation Act for several species, including summer and winter flounder and bluefish. The species in question range widely over the Chesapeake Bay and depend on the aggregate capacity of its habitats for food and refuge, which may collectively be deemed essential to their populations. Because a fish species may use a specific habitat within the Bay does not, however, mean that habitat itself is essential to the Bay populations of those species in the sense that the populations could not be maintained without it. We have extremely limited information on the amount, quality and spatial interrelationships of habitats used by a given species that would allow one to determine quantitatively the extent to which a particular portion of the habitat is critical. Such a designation would require that we understand fully the life cycle dynamics of the species. Accordingly, the designation of Site 104 as critical should not be taken to imply that a species could not persist within the Chesapeake without the habitat afforded by Site 104. However, Site 104 is located in the narrowest reaches of the Bay and contains deep water habitat that is generally warmer than surrounding bottom areas in winter. These two features may suggest that the habitat that Site 104 provides may be of unusual importance, both as a corridor for migrating fish moving to complete their life cycles, and as a thermal refuge during cold winter periods. For example, several species (e.g. river herrings, American shad, striped bass, eel and sturgeons) must pass through the vicinity of Site 104 to successfully complete their life cycle. Any action that degrades local habitat

quality may have a disproportionate effect on the overall populations of these migratory species. Furthermore, white perch, striped bass, sub-adult Atlantic and shortnose sturgeons may use the deep water habitat within Site 104 as a winter refuge from colder adjacent bottom waters. Significantly and irreversibly decreasing the depth of Site 104, by as much as 10 m, could permanently reduce its value as a deep water refuge, forcing the populations to aggregate more intensely elsewhere. This could in turn affect food resources, predation and, ultimately, survival. The reassessment of the Site 104 option should more specifically examine potential effects on the role of the site as a thermal refuge.

Alternatives for Sediment Placement

Are there beneficial uses for this dredged sediment that would result in significant net improvements in Bay habitats or are there actions that can be taken to mitigate the effects of open water disposal?

The placement of dredged sediments back overboard at open water sites strikes some as inherently the most harmful alternative compared to placement in confined sites, either an upland, an island created for that purpose, or the use of these sediments to create or enhance habitats. Furthermore, it is clear that the long-term maintenance of navigation channels in the upper Bay, which will continue to experience high sedimentation rates, will require multiple options including placement of sediment at confined sites and, to the extent feasible, habitat enhancement. Site 104 or, indeed, open water placement in general cannot alone meet the long-term needs for dredged sediment placement. Moreover, although we expressly do not consider the economic costs of alternatives compared to open water placement, economic costs will always limit alternatives. In addition, approaches have been proposed to offset or mitigate the effects of open water disposal, including the use of financial resources from maritime transportation to restore oyster reefs or other habitats. As scientists we observe that debates over the issues of alternatives and mitigation are heavily influenced by preferences, implicit values and economics and have not been structured very well in terms of the long-term health of the Bay ecosystem.

Key scientific questions are: (a) would placement of the dredged sediment proposed for Site 104 result in substantially less deleterious impact on the Bay ecosystem; (b) beyond economic costs, what are the factors limiting the uses of the dredged sediments for habitat enhancement; (c) could there be offsetting actions sufficient to mitigate the effects of open water sediment placement; and (d) how should one go about developing a long-term strategy for dredged sediment placement that optimizes net environmental benefits and economic costs?

1. **All options for placement of dredged sediment have some potentially deleterious environmental consequences. Without careful analyses of these it cannot be concluded that placement of sediments at Site 104 is inherently more deleterious than other alternatives** (uncertainty moderate). It often seems to be assumed that alternatives including upland placement, island creation, and beneficial uses have no

significant environmental impacts or, in some cases, implicit net environmental benefits. This is not necessarily the case. For example, nutrient releases will result from any placement of sediments. As discussed above, the estimate that potential nitrogen losses from hydraulic placement are 2.5 times greater than the nitrogen losses observed at Hart-Miller Island should be considered as an outside estimate. Placement of cohesive masses of dredged sediment from surface vessels could possibly release less nitrogen than that which results from drainage of sediments from containment sites. Moreover, a greater amount of fine sediments may actually escape to be deposited on shallow water habitats during island creation or beneficial use applications than in deep-water placement. Confined placement also leads to oxidation of sediments with the release of acidic drainage with high metals levels. Creation of new islands to contain dredged sediments removes valuable shallow water habitats and could alter circulation and sediment deposition patterns in the Bay. The point is that all of these alternatives carry some environmental costs and benefits that need to be weighed simultaneously rather than in piecemeal or unbalanced assessments.

2. **The fine-grained nature and high water content of the dredged sediments limit their uses in habitat enhancement, but restoration and nourishment of degrading tidal marshes presents a potentially beneficial long-term opportunity** (uncertainty: moderate). The sediments that would be dredged in channel maintenance are predominantly very fine silts and clays that are subject to wave erosion if placed in shallow water and have poor bearing strength. Thus, they would be of limited use in restoration of shallow water habitats, such as oyster reefs. On the other hand, they may find some applicability in the restoration of deteriorating tidal marshes in the Chesapeake Bay. Many Bay tidal marshes are being lost not only to shoreline erosion but as a result of insufficient soil accretion to counteract the relative rise in sea level. These marshes are deteriorating from within. The likely acceleration of relative sea level rise resulting from global warming over the next century will only make this problem worse. Spray application of fine dredged sediments to tidal marshes has been attempted successfully in other areas experiencing rapid relative sea level rise (e.g. the Mississippi delta). Although a carefully observed, pilot-scale demonstration is needed before large-scale implementation in the Chesapeake Bay region, we think there is substantial promise for such beneficial use of dredged sediment.
3. **Ecosystem-based management of the Chesapeake Bay must involve consideration of offsetting mitigation to be effective; controls of urban and suburban nonpoint sources of nutrients and sediments and oyster reef restoration present the most promising opportunities** (uncertainty moderate). There has also been considerable concern about the appropriateness of the application of revenue generated from open-water dredged sediment placement to oyster enhancement as an offsetting mitigation for environmental impacts. Other suggestions have been made in which the Port of Baltimore would contribute financially to the control of nonpoint sources of nutrients, sediments and contaminants as mitigation for potential effects of dredged material placement.

Setting aside concerns about the procedures and policy implications of such mitigation, from an ecosystem perspective such cross-sector mitigation strategies have merit, particularly when placed in a framework in which net economic cost to society and net ecological benefits are simultaneously considered. For example, if the costs of placement alternatives are high and the net environmental benefits are very low, would it be wiser instead to apply some significant portion of the incremental costs to achieve greater environmental benefits elsewhere in the ecosystem? Oyster restoration and controls of nonpoint sources of nutrients and sediments remain great restoration challenges, but could provide substantial benefits. These are promising opportunities for such cross-sector “trading.” Having said that, the adequacy of the existing Department of Transportation-Department of Natural Resources agreement for oyster enhancement as compensating mitigation has not been demonstrated because the benefits are unquantified. One would have to examine both the short-term economic benefits of reseeded the fishery and the longer-term ecological benefits of oyster habitat restoration. The present implementation plan has an emphasis on reseeded of the fishery rather than the rebuilding of reefs for long-term resource recovery.

4. **The scientific knowledge and methods exist to improve greatly the holistic planning of dredged material and ecosystem management in the upper Chesapeake Bay** (uncertainty moderate). While analysis of the costs and benefits, both economic and environmental, in a holistic manner will never be a precise science, understanding and technologies exist to do far better in this regard. Although scientists will forever lament the unknowns, we probably know more about the Chesapeake Bay than any other coastal ecosystem. Technologies exist to model physical and ecological outcomes and to assess environmental costs and benefits in economic terms, including the non-market values of ecosystem services. The Bay management and science communities are in many respects at the leading edge of environmental and resource management and restoration, nationally and internationally. Why shouldn't we also be advancing the frontier of planning for dredged material management in an ecosystem context?

Science and Long-Term Management of Dredged Channels

This assessment was based on a review of the DEIS and the field surveys, experiments and models included in associated reports. We considered these resources in the context of our own scientific experience and judgement. It is an unsolicited and admittedly rapidly prepared assessment intended to contribute to the continued agency analysis and public debate rather than a rigorously quantitative analysis of impacts and alternatives. We intend it to be more catalytic than definitive. In reviewing the DEIS and comments and completing this exercise, however, we were led to the opinion that somehow science has not served policy formulation and decision making related to the long-term management of navigational access as well as it could have.

We need to understand that as long as the port of Baltimore is to be maintained there will remain the need to transfer sediments that are naturally filling up the deeper portions of the bay from one location to another. To date, we have tended to move from one seemingly urgent decision to another and have applied scientific research, monitoring, and modeling in bits and pieces. If society's mutual goal is to maintain an economically viable and environmentally compatible navigation infrastructure, the focus needs to be on the longer term, on multiple options and on integrated assessment. We should be striving toward a design with nature that recognizes the dominant sedimentary processes in the estuary and, at the same time, contributes to ecosystem restoration goals.

The present debate over Site 104 is a case in point. Agencies and the public are forced to consider dredged sediment at Site 104 divorced from an equally full treatment of the ramifications of alternatives. The UMCES scientists who contributed information and analyses to the DEIS assessment were engaged to provide narrow technical data and interpretation rather than being involved collectively as experienced research scientists who are working to understand the ecosystem in a broader context and "to develop and apply a predictive ecology" (the mission of UMCES).

Similarly, the process that led to the development of Maryland Strategic Plan for Dredged Material Management was not strongly supported by scientific assessment. That process started with a large number of options and eliminated those that did not meet certain criteria, rather than with the assistance of integrated scientific assessment that could facilitate the discourse toward optimal environmental and economic solutions. With Maryland's renowned capabilities in ecosystem science and ecological economics we can and should do better. The University of Maryland Center for Environmental Science stands ready to work with all sectors in developing and applying such integrated assessment capabilities.

However, we would like to point out that, in our opinion, in the short term there are only a few things that can be done through sampling, inventory or analysis that can significantly resolve the existing uncertainties regarding the effects of dredged sediment placement at Site 104. Although the maximum nutrient release estimates are based on only a few samples, the degree of refinement that could be accomplished by improved estimates pales by comparison to the influence of factors that would determine how much of the available nutrients would actually be released in sediment placement. Similarly, the uncertainties in applying the estimates of sediment transport developed through laboratory erosion experiments and hydrodynamic modeling are only resolvable by observing the placement of sediments. The issues of changing oxygen conditions over the reconfigured bottom habitat and the potential reduction of thermal refuge habitats should, however, be more carefully addressed in the reassessment. The Center's scientists offer their assistance to all parties in the review and revision of the environmental impact statement for the proposed Site 104 placement.

Contributors

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The UMCES Integration and Application Network

*Surely, scholarship means engaging in original research. But the work of the scholar also means stepping back from one's investigation, looking for connections, building bridges between theory and practice, and communicating one's knowledge effectively to students. Specifically, ...the work of the professoriate may be thought of as having four separate, yet overlapping functions. These are the scholarship of discovery; the scholarship of **integration**; the scholarship of **application**; and the scholarship of teaching. Ernest Boyer, 1990. *Scholarship Reconsidered: Priorities of the Professoriate*.*

The Integration and Application Network (IAN) within the University of Maryland Center for Environmental Science (UMCES) was initiated in 1999 in order to enhance the capabilities of the Center's faculty in synthesis of knowledge across scientific disciplines and applying knowledge for the benefit of society. The Network responds to the convergent interests of the faculty for facilitation of their scholarship of integration and application and the Center's external partners and clients for more effective means to tap the faculty's rich scientific knowledge. We use the term "network" rather than "center" or "institute" because it is intended that IAN will span across UMCES' three laboratories into all corners of our information and knowledge resources and beyond—a virtual nexus.

IAN will inspire, manage and produce timely syntheses and assessments on key environmental and natural resources issues, with special emphasis on the Chesapeake Bay and its watershed and the Mid-Atlantic region. It will aim to complete these more rapidly and articulate results in a manner more understandable by a broad, non-technical audience than is usually characteristic of scientific assessments. Ultimately, IAN will include powerful information networks providing the access and means to consider, analyze, compare and model vast scientific information.

Science and Site 104 is IAN's maiden voyage, but it is illustrative of the breadth of scientific expertise, transdisciplinary thinking, and timely response that the Center plans to bring to bear on important issues. In the not-too-distant future, we will be able to do better by using quantitative models to address "what if" questions and revealing visualizations of complex environmental patterns.