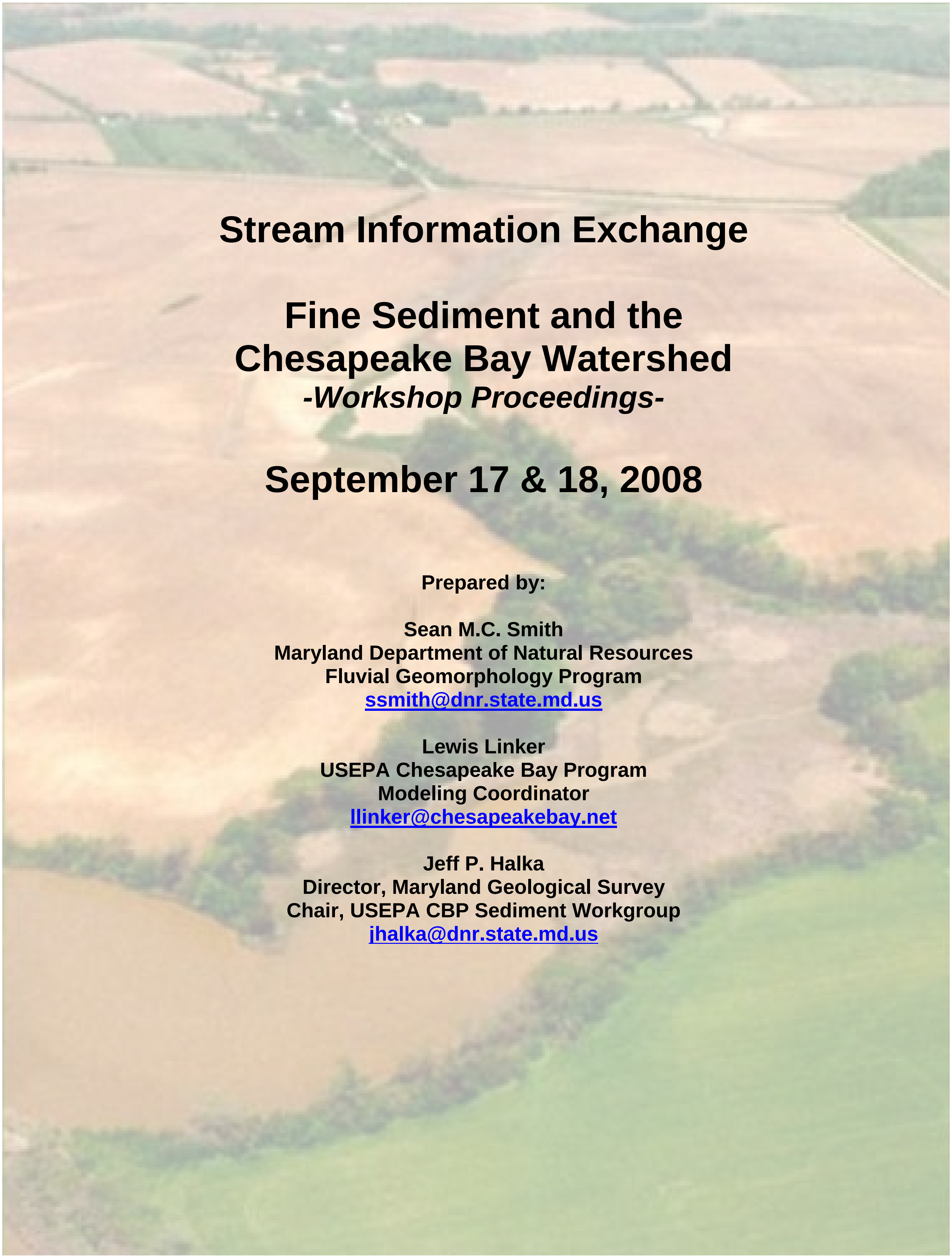

Stream Information Exchange

Fine Sediment and the Chesapeake Bay Watershed

-Workshop Proceedings-

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I. Background

A. Previous Reporting

The 2000 Chesapeake Bay Agreement contained provisions related to the identification and correction of sediment problems, including those associated with the Bay watershed that ultimately affect the Bay's condition. In 2003, a USGS/EPA report, *A Summary of Sediment Processes in the Chesapeake Bay and Watershed* (Langland and Cronin; http://www.mgs.md.gov/coastal/pub/wrir03-4123.pdf), was completed. The report provided an overview of the understanding of general processes related to sediment erosion, transport, and storage in the Bay watershed areas. The main points put forward included the following:

- Understanding estuarine and fluvial sedimentary processes is critical for improving water quality and living resources in the Bay and should provide improved management of stream corridors and protection of eroding coastal zones in the watershed.
- Erosion from upland land surfaces and erosion of stream corridors (banks and channels) are the two most important sources of sediment coming from the watershed.
- The relative contribution of upland sediment and the sediment stored in stream corridors has not been quantified in the bay watershed.
- "Legacy sediment" will ultimately make its way to the Bay. However, it may take decades or longer, depending on its location in the watershed and future climatic and hydrologic factors. Therefore, future improvements in water clarity may take years to decades following implementation of land-use changes in the watershed.
- For the entire Chesapeake Bay region, river basins with the highest percentage of agricultural land use have the highest annual sediment yields, and basins with the highest percentage of forest cover have the lowest annual sediment yields.
- Urbanization and development can more than double the natural background sediment yield. The increase in sediment yield is highest in the early development stages. After development is completed, erosion rates are lower; however, sediment yield from urbanized areas can remain high because of increased stream corridor erosion due to altered hydrology.
- One study in an urban setting estimated 2/3 of the sediment in the water column was from stream banks and 1/3 was from upland erosion.
- Most of the sediment yield from the watershed to the Bay is transported during bankfull conditions, which take place on average every 1-2 years, and during relatively large storm events. Hence, sediment input to the bay potentially can be affected by large-scale patterns of climate change.

Since the time of the report's publication, a number of research and monitoring projects have been completed that have strengthened and expanded the body of knowledge available in 2003. In response to the more recent developments, an "information exchange" was held in September 16 & 17, 2008. The event was intended to provide an opportunity for watershed managers, scientists, regulators, engineers, and environmental restoration professionals to present and obtain new information related to watershed sediment science and policies (Appendix A).

B. Workshop Synopsis

The information exchange workshop, entitled "*Fine Sediment and the Chesapeake Bay Watershed*", hosted presentations on sediment-related processes and observations associated with three scales of resolution, including the landscape (continental and regional), watershed, and reach (a specific length of a river system) levels. Other related information covered included sediment ecology and chemistry by characterizing the role of sediment on aquatic habitat, contaminants, and nutrient flux. The presentations are available for viewing on the web page for the Sediment Workgroup of the EPA Chesapeake Bay Program (http://archive.chesapeakebay.net/calendar.cfm?eventdetails=9724).

The relevance of the workshop presentation information to the 2003 USGS/EPA publication was established in several ways:

a) Validation of past observations and paradigms;
b) Advancement of past observations and paradigms;
c) Additions of new technical details to past the observations and paradigms;
d) Contradictions with past observations and paradigms; and/or
e) Identification of new information needs.

Validation:

- The relation between the rate of soil production and erosion has been framed to demonstrate how contemporary soil conservation is inadequate and erosion rates are unsustainable in many locations (*Montgomery*).
- Measurements and observations of alluvial valley sediment trapping and storage have been acquired from locations in the Coastal Plain, Piedmont, and Blue Ridge physiographic regions (*Hupp, Merritts, Noe, Phillips, Pizzuto, Skalak, Miller*).
- Contemporary erosion rates have been documented to be exceeding historic background rates in all land uses and regions (*Bierman, Gellis, Miller, Montgomery, Ritchie*).
- Elevated levels of contaminants have been observed in urban depositional environments receiving storm-water runoff (*Schueler, Snodgrass*).
- The adverse effects of fine sediment on freshwater habitats remains a concern (*Morgan*).

Advancements:

- Detailed physical characterizations of alluvial valley sediment storage deposits have been completed in several locations in the Piedmont and Blue Ridge physiographic regions (*Merritts, Miller, Pizzuto, Skalak*).
- Contemporary Coastal Plain alluvial valley sediment trapping characteristics have been quantified in numerous locations below the Fall Zone (*Hupp, Noe, Phillips*).
- Approaches have been developed for the measurement of in-channel sediment storage and quantification of the relation of the storage mass to watershed sediment yields (*Miller, Skalak*).
- Sediment fingerprinting and radio-nuclide analyses have been used to estimate relative sediment source contributions from hillsides and channels in Piedmont watersheds (*Devereux and Prestegaard, Gellis, Ritchie*).
- Short-term measurements of bank erosion and estimates from sediment isotopic fingerprint analyses have indicated that bank erosion contributions to sediment loads may be substantial in some locations within Piedmont watersheds (*Devereux and Prestegaard, Gellis, Merritts*).
- Watershed sediment budgeting evaluations, dendro-chronology, and floodplain mapping/stratigraphy have indicated that contemporary floodplains are currently storing substantial portions of the sediment load yielded from upstream hillslope and valley areas (*Hupp, Miller, Pizzuto*).
- HSPF and SPARROW model development has been completed for application in large watersheds (*Brakebill, Currey, Shenk*);
- Documentation of the successful performance of an impervious cover model for the evaluation of storm-water problems, including those related to sediment, in relatively small urban watersheds has been compiled (*Schueler*).

Additions:

- Contemporary Coastal Plain nutrient flux associated with sediment trapping has been quantified in alluvial valleys below the Fall Zone (*Noe*).
- The effect of colonial-age sediment deposits in contemporary reach-scale sediment budgets has been quantified in several locations of the Piedmont and Blue Ridge physiographic regions (*Pizzuto*).
- Morphological adjustments, including channel/valley storage, floodplain surface aggradation, and channel bank erosion, have been measured in valley reaches known to have contained historic mill dams (*Merritts, Pizzuto*).
- The mechanics of channel and floodplain adjustment have been organized to allow for the simulation of alluvial valley sediment flux over extended time periods (*Lauer*).
- The relevance of mountain mass wasting to stream management in the Blue Ridge physiographic region has been characterized through consideration of related climatic event frequencies and resulting magnitudes of erosion and sediment supply (*Eaton*).
- Background landscape erosion rates have been estimated using isotopic analyses in several of the physiographic regions within the Bay watershed (*Bierman*).

Contradictions:

- Calculations have been assembled and observations have been made that demonstrate how large, rare storm runoff flows have a dominant influence over smaller, frequent storm flows on cumulative long-term sediment loads in the Chesapeake Bay region (*Vogel, Eaton, Bierman*).
- The long-term erosion rate estimates derived from isotopic analyses are greater than short-term (contemporary) erosion rates calculated from measured watershed sediment loads, indicating that "large" events that have historically influenced the physical conditions in the Bay region have not yet been observed first-hand (*Bierman, Vogel*);
- Results from isotopic analyses indicate that long-term erosion rates are insensitive to land use and lithology (*Bierman*).
- High sediment loads measured from urban hillsides indicate that urban land areas, once assumed to be sediment "starved" following development, may produce significant sediment supplies (*Miller, Schueler*).
- Observations of the potential limitations of the Universal Soil Loss Equation and traditional sediment delivery metrics for the simulation of sediment processes in large watersheds have been compiled (*Boomer*).
- Interpretations of channel profiles and sediment loads have indicated that "equilibrium" concepts in fluvial geomorphology may not provide appropriate guidance for stream management (*Phillips, Vogel*).
- Measurements of fine sediment deposits within the stream channels have been acquired that demonstrate that sediment storage is occurring within active channels in the Piedmont (*Miller, Skalak*).

Needs:

- A more extensive network of continuous stream flow monitoring gauges is needed to support sediment monitoring, modeling, and budgeting.
- Watershed sediment budgeting in many additional physiographic and land use settings is necessary to clarify the timing and magnitudes of sediment supplies and storage, and to better characterize watershed sediment pathways.
- Better information on floodplain sediment residence times in different settings and land use conditions is necessary to forecast the delivery of hillslope sediment supplies to large rivers and the Chesapeake Bay.
- The role of gully channel erosion and adjustment needs to be more extensively quantified in watershed sediment budgets compiled in different physiographic and land use settings.
- The long-term cumulative effects of sediment and associated contaminants on aquatic habitat need to be more intricately assessed.

C. Attendee Responses

To obtain a sense of where the Chesapeake Bay science and management community stands with respect to comprehension of fine sediment processes and related watershed management issues, a workshop focus on two over-arching questions was proposed. Speakers, moderators, and attendees were asked to consider these questions relative to the information they present or hear at the workshop. Reporting of responses was accomplished through notes collected by the workshop session moderators, comments from participants, and compilation of responses prior to a moderated synthesis session on the last day of the workshop. The questions were focused on identification of knowledge gaps and the performance and implementation of related best management practice. The responses were compiled as simple bulleted statements responding to each of the two questions (See Appendix B).

Question 1: What are the key knowledge gaps in watershed sediment modeling, monitoring, and assessment?

Question 2: What are the most effective best management practices for reducing fine sediment loads to the Chesapeake Bay?

D. Overview of Findings

The “ultimate” long-term source of sediment in the Chesapeake Bay watershed has historically been hillslope erosion. This remains true in the contemporary landscape. Erosion and the resultant sediment loadings generated within and moving out of the watersheds draining to the Chesapeake Bay remain problematically high. They are not only high during periods of urban construction and on actively tilled cropland, but can also be found to exceed estimated historic “background” erosion rates in all land cover conditions and lithologic settings within the region. This trend is partly due to the effects from historic episodes of anthropogenic disturbance in many locations. The contemporary erosion rates carry economic costs in terms of agricultural land conservation and stream management, and can create problematic conditions for aquatic communities and downstream depositional environments, including the Chesapeake Bay.

The movement of hillslope-supplied sediment to the Chesapeake Bay estuary requires passage through alluvial valleys that act as regulators of the watershed sediment yield. The effect of the alluvial valley pathway in terms of alleviating or contributing to the excessive hillslope supplies can be spatially and temporally varied. This is partly due to multiple factors that influence the sediment supplies and the hydraulic efficiency of stream valleys. This limits the ability to make broad assumptions on the timing and delivery of historic (colonial-age) and contemporary sediment to large rivers, reservoirs, and the Chesapeake Bay, as well as on the net contribution of valley areas to annual watershed sediment yields.

Detailed evaluation of the sediment contributions from hillsides compared to those from gully and alluvial channels has not been completed in most of the sub-watersheds draining to the Bay. Links between sub-watershed sediment sources and outlet yields have not been well defined, particularly in headwater basins that occupy the largest portion of the landscape. Alluvial valleys have been observed to operate inconsistently in terms of adding to the net watershed sediment supply or subtracting from the hillslope-derived sediment load conveyed to a reach. The mass of sediment stored within valley floodplains has been found to constitute a considerable portion of the amount of sediment supplied from upstream tributaries and valley stream bank erosion in three different physiographic provinces in the region. However, observed rates of erosion measured at breached mill dam deposits in the Piedmont indicate that "hot-spots" of alluvial channel sediment supply can exist in some locations. Coastal Plain environments have been extensively characterized as being sediment "bottle-necks" that can reduce the loads conveyed to the Chesapeake Bay by storing sediment over extended periods of time. More detailed information on their hydraulic performance is needed to describe actual load reductions and durations of storage that occur as flows traverse the region towards the estuary.

More extensive sediment budgeting efforts in more locations can help answer watershed sediment supply, delivery, and pathway questions. River flow and sediment monitoring at more stations will be necessary to address the relatively large uncertainty with the estimation of sediment loads in basins where there have been no direct measurements. The same sources of uncertainty impair the accuracy of watershed sediment budgeting terms and the ability to achieve a useful resolution for watershed sediment modeling and the targeting of best management practices. Continuous sediment discharge monitoring using turbidity measurements as a surrogate for suspended sediment sample extractions may help improve the accuracy of sediment load estimates with reduced costs compared to past methods. Sediment fingerprinting may provide a relatively cost-efficient option for sediment source identification when more detailed budgeting measurements and gauging are not feasible.

To conclude, several advances in the understanding of watershed sediment processes have been made over the past five years. However, the high erosion rates and sediment yields characterizing the contemporary condition of the Chesapeake Bay watershed will require additional management investments to correct. The need to pursue effective and cost-efficient sediment management activities justifies greater investments in the quantification of sediment flux in more locations with the goal of characterizing conditions in all of the major watershed land uses and geomorphic settings in the region. There is currently limited information to intricately describe the holistic and long-term effects of varied sediment flux trends on desirable ecological conditions. This relegates managers to the consideration of generalized estimates of "background" and contemporary erosion rates, approximations of sediment flux, and conceptual characterizations of the hillslope and fluvial conditions associated with those rates. The unavailability of high resolution information that describes the relations between sediment flux, water quality conditions, and aquatic habitat limits the capacity to make watershed management decisions and investments. Pre-European settlement sediment flux conditions, in themselves, may no longer be attainable in many areas of the contemporary landscape, making their use as a management goal problematic. More realistic goals for the rehabilitation of stream, river, and estuarine ecosystems can only be sorted out with more intricate sediment information, including the rates of supply, watershed pathways, delivery mechanisms, cumulative yield trends, and associated ecological effects.

II. Landscape Scale

The landscape level of evaluation covered concepts related to sediment erosion and yields that are characteristic of large areas, such as a physiographic province or the Mid-Atlantic region.

Watershed sediment yield rates in the Eastern United States have been evaluated using radio-nuclides. The estimates indicate that "background" erosion rates averaged 18m/Myr, which can be converted to a sediment yield that is ~50t/km^2/yr (*Bierman*). The estimated long-term erosion rates are greater than the erosion rates calculated using the relatively short sediment data records from USGS gauging stations, possibly indicating the influence of very large sediment transport events that have yet to be measured. This possibility is supported by long-term erosion and yield estimates in the Susquehanna basin of 15m/My and 42t/km2/yr, compared to estimates from short-term sediment yield records of 8m/yr and 22t/km2/yr. The evaluation of the half-load discharge in the Susquehanna River basin has also supported this perspective by providing evidence that relatively rare floods transport the most sediment over the long-term (*Vogel*).

Rates of erosion over long time periods are not only influenced by the hydraulic transport of sediment by precipitation runoff, but also mass wasting during "extreme" climatic events. The implication is that infrequent events can be responsible for large portions of the long-term sediment load from mountainous watersheds in the Bay watershed. Many mountain-side (hill-top) streams have been created and shaped by low frequency, high magnitude sediment supply events that have been estimated to occur an average of once in ~2500 years in the Blue Ridge physiographic province (*Eaton*). Contemporary stream management approaches are incapable of controlling channel dynamics associated with such large-scale events. In contrast, the receiving lowland rivers have been heavily influenced by high frequency, low magnitude sediment supply events.

In more intermediately sloped landscapes, destructive soil erosion has been significant on all of the earth's continents since the development of the plow for cropland production, resulting in sediment loads that are elevated compared to the long-term background values. While improvements have been made to minimize soil losses through practices such as conservation and no-till farming, the rate of soil losses still exceed rates of soil production in many agricultural land areas (*Montgomery*[a,b]). The

historic average global geologic rate of soil erosion is estimated to have been 0.029mm/yr, compared to the mean rate of soil production of 0.017mm/yr. The present rate of erosion under conventional agriculture is estimated to be 1.537mm/yr. The USDA soil loss tolerance range, 0.4 to 1mm/yr, also exceeds sustainable average soil production rates. In contrast, erosion rates associated with hillsides with native vegetation and no-till agriculture are estimated to average 0.013mm/yr and 0.082mm/yr, respectively, both of which are below the estimated rate of soil production.
Ninety percent of all sediment eroded from upland areas has been estimated to be stored in the fluvial system before entering estuarine or marine environments (*Hupp*). The river systems in the Coastal Plain physiographic region have been observed to operate as sediment "bottle-necks" upstream from estuaries such as the Chesapeake Bay (*Phillips*). The Fall Zone transition from the Piedmont to Coastal Plain creates a regime shift from high energy bedrock controlled rivers to relatively low energy reaches with extensive inundation and riparian retention of sediment (*Hupp*). As such, Coastal Plain floodplains can generally be characterized as aggrading systems with relatively low erosion rates (*Noe*).

Within the Chesapeake Bay watershed, isostatic corrections of the earth's tectonic plates that are associated with past glacial advances are believed to have pushed up the land surface, thereby being partly responsible for the bedrock knick-point elevations in the Fall Zone locations such as Great Falls of the Potomac River. Conversely, the glacial retreat that commenced ~20,000 years ago is believed to have reversed that trend, resulting in the collapse of the maximum fore-bulge and subsidence of the Chesapeake estuary region (*Pavich*). This subsidence is estimated to account for up to one half of the estimated rate of sea level rise, ~4mm/yr, resulting in an increase in the space to accommodate fine sediment in the Chesapeake Bay.

III. Watershed Scale

Watershed sediment flux has been evaluated using a variety of approaches, including:

- sediment fingerprinting (*Gellis, Devereaux and Prestegaard, Ritchie*);
- calculations using data from river flow gauging and suspended sediment sampling to estimate sediment loads and their relative significance (*Miller, Vogel*);
- surrogates for suspended sediment sampling, such as continuous turbidity measurements to estimate sediment concentrations (*Miller, Jastram*);
- modeling to simulate rainfall runoff and related sediment flux (*Shenk*); and
- statistical relations between watershed conditions and sediment loads (*Brakebill, Boomer*).

Sediment fingerprinting using naturally occurring chemical tracers and radio-isotopes has been attempted in several Chesapeake Bay watersheds to identify the primary contributors of fine sediment to watershed sediment yields (*Ritchie*). Evaluations of long-term landscape erosion rates evaluated using 10-Be have been found to be insensitive to lithology or land use (*Bierman*). This observation is contrary to results from evaluations of contemporary processes using fingerprinting and stream gauge data that have indicated that dominant watershed sediment sources can vary by physiographic region and land use (*Gellis, Devereaux and Prestegaard*). Consistent watershed land use signals have not been clearly identified using the fingerprinting techniques, but seasonal trends in watershed sediment sources have been observed and distinct signals appear to be associated with Piedmont and Coastal Plain provinces (*Devereaux and Prestegaard*). 137-Cs has also been successfully used in Piedmont depositional environments as a stratigraphic marker to document rates of sediment accumulation since the onset and peak of atomic testing in the twentieth century (*Ritchie*).

Although sediment fingerprinting provides a potential tool for sediment source identification, the quantification of sediment loads requires additional information about the rate of sediment transport. The traditional method for acquiring such information relies on flow gauging and suspended sediment sampling for the development of a sediment rating curve. Rating curves relating sediment discharges to a flow discharge can introduce "spurious correlation" that can bias results because flow discharge is associated with both the dependent and independent variables used in the rating. This issue supports the evaluation of sediment concentrations and discharge (*Vogel*). Use of a rating curve implies that storm flow sediment load estimates derived from the rating curves conform to the trends observed during a subset of other storms, which introduces uncertainty. Suspended sediment samples representing daily time intervals also introduce uncertainty because of the unclear relation to instantaneous concentration values, thereby rendering them inadequate to characterize storm loads or rating curves. The use of continuously acquired turbidity measurements can provide a surrogate capable of sampling sediment concentrations commensurate with monitored flow rates over the duration of a hydrograph. The approach may offer a more cost efficient means to monitor suspended sediment trends, requiring a smaller number of suspended sediment samples for load determinations (*Miller, Jastram*).

Knowledge of detailed sediment budgets in small and large watersheds draining to the Chesapeake Bay remains limited. Sediment budgets alone are not enough to resolve specific river management and hydraulic design problems, but they do offer the potential to improve the understanding of watershed sediment pathways (*Pizzuto*). Surficial erosion cannot be ruled out as a significant contributor to sediment loads, even in urban watersheds, as indicated by data from Maryland's Piedmont (*Miller*). Sediment fingerprinting results have identified cropped fields as being the dominant sediment sources in a lower Eastern Shore Coastal Plain watershed dominated by agricultural land uses (*Gellis*). Stream banks have been identified as a source of sediment in a Piedmont agricultural watershed characterized by carbonate lithology in Pennsylvania (*Gellis*). Stream banks have also been identified using fingerprinting techniques as having a dominant influence on sediment load contributions in Piedmont areas characterized by a crystalline bedrock lithology in Maryland (*Devereaux and Prestegaard*). Although channel bank erosion may be a substantial component of urban sediment budgets, the percentage of the eroded mass that reaches watershed outlets remains unclear (*Miller*).

Sediment storage within a drainage network can substantially influence cumulative watershed sediment yield trends. Valley storage of the colonial-age sediment, described in the 2003 synthesis of sediment processes, has been observed in the Piedmont to have been exacerbated by mill dam construction during the time of large-scale sediment erosion from poorly managed agricultural and logged lands (*Merritts*). Channel storage may also be a significant component of watershed sediment budgets in some settings (*Miller*). As sediment moves in rivers flowing from the Piedmont to Coastal Plain physiographic regions, it may be re-deposited multiple times before reaching the Chesapeake Bay (*Phillips*). As a result, sediment delivered to estuaries can often be assumed to be from local reworked storage deposits. Unfortunately, river gauging networks may be located too far upstream to accurately account for the storage dynamics characteristic of many Coastal Plain alluvial valleys.

The limited extent of continuous watershed sediment flux data requires that quantitative evaluations be pursued using model simulations. The sediment pathway in Phase V of the Bay watershed model includes edge of field sediment supply estimated using four parameters related to sediment generation, rainfall detachment, attachment, and wash-off, and coefficients that account for best management practice factors, land acreage, and delivery to streams (*Shenk*). Sediment supply calibration relies on erosion estimated from the Universal Soil Loss Equation (USLE) and the National Resources Inventory (NRI) soil erosion database with grain sizes guided by STATSGO size classes (U.S. EPA, 2008). Independent examination of the performance of USLE has shown poor correlation between its predictions with observed sediment yields, generating criticism of USLE use in watershed-scale sediment simulations (*Boomer*). The disparity in the USLE and measured values may be attributed to the differences in the spatial scale of the plot scales used in USLE development compared to the watershed scales at which it is applied. More specifically, error with the watershed scale application may be attributed to the ability to accurately quantify the delivery of sediment from eroded hillsides. The factor used to estimate sediment delivery to streams is derived using the SCS method with drainage area as the independent variable. Tests of USLE with multiple sediment delivery metrics have shown poor correlation between modeled and observed sediment load values. Near stream gully formation and in-stream bank erosion has been acknowledged to be able to account for large portions of the observed sediment loads, as well as USLE modeling errors.

To augment the information provided by the Chesapeake Bay watershed model by evaluating the influence of specific watershed characteristics, a spatially referenced non-linear regression model has been constructed to relate mean annual sediment flux to likely sources and transport factors (*Brakebill*). Factors found to influence sediment yield trends included basin slope, reservoir density and size, physiography, soil permeability, and stream size. Stream corridors above the Fall Zone were observed to be a net sediment source and larger streams and impoundments were found to be net deposition locations.

Mathematical models have also been popularized for use in estimating the effectiveness of flows at passing sediment. Two discharge indices can be considered to enhance the understanding of sediment loads, including effective and half-load discharges (*Vogel*). The former has been observed to vary by river, with only a small portion of the cumulative sediment load being carried by the effective discharge. Accordingly, the effective discharge has limited benefit for comparisons of sediment loads between river systems The half-load discharge may provide more relevant information on the relation between river discharge and sediment loads, and the characteristic ability of a river system to carry sediment. A reason for the enhanced utility of the half-load discharge is due to the consideration of the cumulative total mass of transported sediment, compared to the maximum transport value. When evaluated, the result indicates that rare infrequent floods are responsible for transporting the most sediment.

IV. Reach Scale

The river networks conveying sediment from hillsides into and through alluvial valleys and eventually to the Chesapeake Bay adjust by a complicated set of hydraulic process involving the conveyance of water and sediment. Erosion and deposition can add or subtract from the sediment load and affect the condition of the channel in planform, cross section, or profile. With respect to the latter, the concept of “equilibrium” has been a long-standing paradigm in fluvial geomorphology to describe the condition under which a channel reach is adjusted to pass the load it receives over a graded time scale, usually thought to be on the order of a century. However, equilibrium may be a poor concept to rely on to describe contemporary fluvial processes (*Pizzuto*). Rivers are rarely in a graded “steady state” condition, most having concave profiles with localized convexities, so equilibrium cannot reasonably be assumed (*Phillips*). Accordingly, an “equilibrium” channel condition may not be a practical or appropriate goal in river engineering or rehabilitation efforts. The influence of the multiple, often inconsistent, anthropogenic factors further complicates river processes and invalidates the assumption that steady-state “graded” conditions can be attained.

Extensive research has been undertaken in the past five years to improve the understanding of processes affecting channel adjustments in alluvial valleys. The mechanics of adjustment affecting channels and their floodplains have been broadly discretized into “extension” and “shaving” modes, both of which can occur if the channel is not in equilibrium and can be equal in magnitude (*Lauer*). Extension is the elongation of the channel centerline due to the growth of the internal point bar being less than the extension of the opposite cut bank. Shaving is the results from point bar being lower than the eroding cut bank on the opposite side. Collectively, use of this framework has the potential to assist in the evaluations of valley morpho-dynamics and related sediment flux that affects sediment delivery to large rivers and estuaries.

Floodplain storage can be an important component of watershed sediment budgets. Storage changes can be difficult to measure in many floodplain areas, particularly if the stored volume is a relatively small depth of accumulation over a large valley surface area. Depths <10cm can be negligible in terms of modifying floodplain topography. For example, floodplain deposition is a significant component of the South River (Virginia) watershed sediment budget, but overbank deposition has not significantly altered the floodplain topography (*Pizzuto*). Sedimentation in Coastal Plain floodplains has been observed to vary from 0 to 10mm/yr, depending on location (*Hupp, Noe*).

Locations where some of the deepest accumulations of sediment thought to have been derived from post-colonial erosion stored are coincident with the locations of historic mill dams in alluvial valley floodplains (*Merritts*, *Pizzuto*). Post-dam breaches can result in temporally and spatially varying erosion rates of the stored sediment, resulting in an eventual flushing of large quantities of sediment from the pond area. The average time for flushing available stored sediment has been estimated to be about 150 years using data from four sites in the Little Conestoga River in Pennsylvania (*Merritts*). The cumulative pond-derived sediment load to the Little Conestoga River after four decades and one hundred dam breaches has been estimated to be ~2 million cubic meters, or ~50,000m^3/yr. However, the influence of mill dams on stored and long-term releases of sediment vary by river basin and location (*Merritts, Pizzuto*). For example, bank erosion is not one of the three largest terms in the South River sediment budget despite the fact that erosion rates have increased by a factor of two during the middle part of the 20th century, possibly due to mill dam losses (*Pizzuto*). Less than one fifth of the mass of the sediment yielded from a reach of a Maryland Piedmont stream valley has been observed to be comprised of legacy sediment (*Pizzuto, Miller*).

Both bank erosion and tributaries have been observed to be substantial sources of sediment to higher order streams (*Pizzuto*). Gullying in headwater basins may generate larger sediment contributions than remobilization of stored valley floodplain deposits in some watersheds (*Miller*). Contemporary floodplain sedimentation rates have been observed to be highest where alluvial streams receive runoff from tributary watersheds with high sediment loads (*Hupp*). The amount and timing of sediment movement to watershed outlets is unknown in most of the tributary watersheds draining to the Chesapeake Bay (*Pizzuto, Miller, Hupp*). Spatially scaled sediment yield measurements from a Piedmont watershed have been used to estimate that the mass of sediment reaching fifth order waterways is substantially less than the amount yielded from first order basins, indicating that contemporary floodplains store contemporary sediment in many locations (*Miller*). The percentage of the sediment load retained within Coastal Plain alluvial valleys has been found to increase with increases in the available floodplain area, and decrease with the sediment load to a reach. The total amount of floodplain sediment trapping also increases with the increases in loads (*Noe*).

The retention times of stored floodplain sediments are poorly understood in most locations (*Hupp*). Though, efforts in the South River of Virginia have partitioned sediment deposits by their period of formation in the early or later half of the twentieth century using sediment mercury concentrations as indicators (*Skalak, Pizzuto*). Localized imbalances can be expected, even in graded systems (*Lauer*). Floodplain shaving and extension dynamics can be associated with different types of sediment material. Sand has been observed to interact strongly with the floodplain, cycling in and out in multiple bends. Fine sediment supplied to a reach can spend long periods of time in residence (*Lauer*). Artificially channelized reaches in the Coastal Plain have been observed to trap up to ten times less sediment than unchannelized reaches (*Hupp*).

Fluvial systems also have the capacity to store sediment with in the active channel. Channel storage has been observed to comprise approximately a third of the annual load in a monitored Piedmont watershed, with scour from the deposits estimated to comprise a volume equivalent to less than ten percent of the annual load (*Miller*). Fine-grained river channel margin deposits have also been observed to store about a quarter of the annual sediment load in the South River in the Blue Ridge physiographic province (*Skalak*). Conditions that create them are characterized by low flow velocities resulting from debris or other obstructions in the active channel that cause the settling of mud, sand, and organic matter. Such deposits have been estimated to account for slightly more than a quarter of the annual sediment load by volume. The volume of the deposits estimated to be reworked through erosion and deposition is equivalent to only about five percent of the estimated annual load.

V. Sediment Ecology

Although fine sediment is a natural component of stream ecosystems, over-abundance can adversely change physical habitat conditions by altering the structure and function of physical habitat conditions, such as the condition of stream substrates (*Morgan, Snodgrass*). Excessive fine sediment can also impair the physiology of aquatic organisms. Surveys have shown correlations between higher fish biomass and stream conditions characterized by lower turbidity conditions and high indices of biological integrity. Salmonid species are particularly sensitive to fine sediment inputs due to destruction of their spawning redds. Higher turbidity correlates with higher stream bottom “embeddedness”, which has been correlated with lower fish abundances. Streams impacted by fine sediment have been observed to take up to fifteen years to recover after supplies have been reduced (*Morgan*).

Fine sediment can also impact stream ecological conditions by being vectors for the accumulation and movement of metals, nutrients, and other contaminants. Stormwater ponds are locations of accumulation of both fine sediment and associated metals. The heavy metals adsorbed to fine sediment in depositional areas receiving stormwater runoff can have toxic effects, impairing the ability to provide habitat for amphibian populations (*Snodgrass*). Heavy metal movement within rivers has been evaluated in the Blue Ridge physiographic province, with a focus on mercury (Hg) (*Skalak*). The approach evaluated characteristic Hg concentrations from two different time periods, followed by coupling of the concentrations with a reach-based sediment budgeting framework. The work has concluded that it would take several decades to reduce majority of the mass of Hg in the study reach channel.

Rates of nutrient accumulation have also been measured in association with sediment deposition in Coastal Plain valley floodplains (*Noe*). The accumulations were estimated to comprise median values of 24, 59, and 119% of the annual loads of nitrogen, phosphorous, and sediment, respectively. Floodplain nutrient retention was concluded to increase with the available floodplain area and decreases with the load to a reach.

VI. Sediment Management

Seventy percent of Maryland's 8-digit watersheds have been listed as being impaired for sediment (*Currey*). For evaluations of the regulatory total maximum daily load, a reference watershed approach has been used that considers the allowable load beyond "natural" conditions. The Phase V version of the Chesapeake Bay model is being used for watershed simulations used to support both the Chesapeake Bay Program initiatives and TMDL regulatory fulfillment (*Shenk*). Supporting efforts to develop better sediment flux estimates should focus on the gaps in watershed sediment modeling, monitoring, and assessment, while also addressing the gaps between those same three activities (*Currey*).

Stormwater runoff monitoring has shown that the grain sizes ranging from 0.25 to 1.0mm contribute the greatest percentage of nutrient and metal contaminants by sediment size fraction, compared to other size fractions (*Schueler*). An impervious cover model (ICM) has successfully been used to stratify types of stormwater management that is capable of changing runoff rates, thereby affecting sediment yields (*Schueler*). Areas with low impervious cover have been found to correlate with good water quality and quantity, whereas areas with high pervious cover have been correlated with water quality problems. Of 65 peer reviewed studies testing the model, 72% confirmed the predictability of the ICM and 28% were inconclusive or contradicting, with the latter studies being located in larger watershed with complications from legacy problems, dry weather water quality and baseflow conditions.

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Appendix A: Speaker contact information and presentation background information

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Presentation Title: Rates of making and moving sediment in the Appalachians - the power of isotopic analysis

Highlights:
Isotopic measurements provide a powerful toolkit for understanding long-term, background rates at which sediment is generated. Such data are critical for responsible, cost-effective management, particularly in setting reasonable and appropriate goals for long-term sediment loading to the Bay. I'll review the use of these systems around the world with a focus on data that we and others have gathered from the central Appalachians and Piedmont.

Kathy Boomer / Donald E. Weller / Thomas E. Jordan

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Presentation Title: Utility of hillslope-based empirical models to predict sediment discharge in the Chesapeake Bay watershed.

Highlights:

- Many watershed models developed to predict stream sediment loads rely on empirical studies relating erosion rates to local field conditions. In particular, the Universal Soil Loss Equation and its derivatives are widely used for identifying sub-basin areas with a high potential for degrading stream water quality.
- When we compared sediment loading rates estimated from regional application of the USLE and sediment delivery ratios (SDRs) with observed loads for than 100 basins throughout the Chesapeake Bay Watershed, however, we found a poor correlation between observed and predicted values.
- Our results confirm that edge-of-field estimates cannot be used for watershed applications and indicate that basin-wide hillslope processes may not drive sediment delivery. Near stream gully formation and in-stream bank erosion may account for much of the observed sediment loads.

John Brakebill

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Presentation Title: Relating sediment sources to fluvial sediment flux in the Chesapeake Bay watershed: An application of the SPARROW model

Highlights:
We apply a regional approach to describe the spatial distribution of fluvial sediment supply, transport, and storage in non-tidal streams and drainages of the Chesapeake Bay Watershed. A spatially referenced, nonlinear regression (SPARROW) model is used to relate the estimated mean annual flux of suspended sediment in 129 non-tidal streams to likely sources of suspended sediment and transport factors. Modeled sources include agricultural and forest lands, urban development, and stream channels documented over the early 2000 time period. Urban development yielded the greatest amount of sediment per unit area, although agriculture was much more widespread, and the largest overall suspended sediment source. Factors facilitating or limiting the transport of sediment over land and within the stream corridor include: mean basin slope, reservoir density, reservoir size, physiography, soil permeability, and stream size. Small stream-corridors above the Fall Line are a net source of sediment; net deposition (storage) occurs along larger streams in the Coastal Plain where slopes and velocities are lower; and in impoundments where residence times are longer. The quantification and understanding of sediment sources and physical factors affecting sediment transport and storage is directly applicable to the regional management of sediment in fluvial or estuarine settings like Chesapeake Bay and its watershed.

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Presentation Title: Maryland Sediment TMDL Development - A Partnership Approach to Managing Multiple Endpoints

Highlights:
- Maryland's challenge is that 70% of the MD 8-digit watersheds are listed as impaired by sediment with many having multiple endpoints resulting from differing water body types and water quality standards. In addition, many of these listed watersheds cross State jurisdictional boundaries.
- MDE entered into a partnership with the Chesapeake Bay Program to provide resources towards a community model that could be applied as various scales to support multiple objectives.
- In the absence of sediment criteria in non-tidal streams, MD applied an innovative reference watershed approach that considers the allowable load beyond natural conditions.
- Tidal water quality criteria was adopted by Maryland with supporting scientific documentation by the Chesapeake Bay Program.
- Addressing multiple endpoints by applying components of the same model is expected to result in improved consistency when considering local vs. downstream sediment impacts.

Olivia Devereux / Karen Prestegaard

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Affiliation 2: University of Maryland, Department of Geology, College Park, Maryland 20742, Phone: 301-405-6982, Email: kpresto@geol.umd.edu

Presentation Title: Use of sediment fingerprinting techniques to evaluate sources of fine sediment in the Anacostia River

Highlights:
Chemical composition of watershed soils and suspended sediment samples were collected and analyzed to evaluate the contributions of soils from various land uses and topographic positions to total suspended sediment load. Sediment from various land-uses could not be distinquished from one another in this urban watershed. Sediment from the Piedmont portion of the watershed could, however, be distinquished from the Coastal Plain sources. Sediment from various topographic positions (upland, bank, floodplain, and streets) could also be identified. Results from the 2005-2006 water years indicate that sediment was primarily derived from western, Piedmont sediment that was eroded from bank sites.

L. Scott Eaton

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Presentation Title: The role of debris flows in long term landscape denudation and evolution in the central Appalachians

Highlights:
- A study of recent and prehistoric catastrophic floods in the central Appalachians has revealed the following observations:
- In two separate storms, up to 30 inches of rain fell within a day period, triggering over a thousand debris flows.
- Radiocarbon dating of prehistoric debris flows indicates a recurrence interval of one event every 2000-3000 years for individual mountainous drainage basins, and every three-to-five years when considering the entire southern and central Appalachians.
- These events transport large volumes of sediment from the mountains to the flood plains. Roughly half of the sediment that would be expected to be delivered to the lowlands over several thousand years through 'normal stream flow' arrives in one day from debris flow events.
- These finding suggests that sediment transport in the headwaters of the Appalachians is episodic, thereby affecting the rate of sediment supply and transport to the Chesapeake Bay.

Allen Gellis

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Presentation Title: Sediment sources in the Chesapeake Bay watershed: Scales and approaches

Highlights:

- Sediment is an important pollutant affecting water quality and habitat in the Chesapeake Bay and its watershed. In order to reduce erosion and sediment loadings, it is important to identify the significant sources of sediment.
- This presentation will highlight tools and approaches used to understand and quantify the important sources of watershed-derived sediment in the Chesapeake Bay. Depending on the watershed scale of interest, certain approaches may be more plausible than others. At the largest scale, models and fluvial sediment data may be appropriate. At the smallest scale, determining sediment sources using geochemical fingerprints and sediment budgets may be a desirable approach.

Cliff Hupp

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Presentation Title: Floodplain sediment trapping and storage along tributaries to the Chesapeake Bay

Highlights:

Floodplains along tributaries to the Chesapeake are a critical element in the maintenance of water quality by trapping and storing large amounts of sediment and associated contaminants. These floodplains are among the last places for sediment storage before entering critical estuarine nursery areas for fish and wildlife. We have monitored sediment deposition along 10 streams using dendrogeomorphic and artificial horizon (clay pad) analyses. Extensive riparian wetlands within the Coastal Plain regions of the Bay may trap as much as 70,000 kilograms of sediment per year along a 2-kilometer reach. However, discrete net deposition rates vary from near 0 to 8 mm/yr; some locations near levee crevasses are erosional while others near hydraulically connected sloughs have the highest deposition rates. Sedimentation rates are highest where alluvial streams receive runoff from either agricultural or urbanizing areas with high-suspended sediment loads. Channelized reaches trap 10 times less sediment than unchannelized reaches with typical overbank flooding regimes. Substantial amounts of nutrients (N and P) may also be stored with sediment permitting biogeochemical remediation. Quantification of fluxes in floodplain sediment is necessary for estimation of sediment budgets; while net trapping information may now be available, retention time remains poorly understood.

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http://waterdata.usgs.gov/va/nwis/current/?type=quality

Presentation Title: Sediment Monitoring in Small Urbanized Watersheds of Fairfax County, VA

Highlights:

- Introduction of a recently initiated study measuring sediment and nutrient transport in small urbanized watersheds.
- Discussion of methods used, including real-time turbidity sensors and automatic samplers with multivariate triggering algorithms.
- Brief discussion of other turbidity-based sediment studies in Virginia.

J. Wesley Lauer

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Presentation Title: Modeling net downstream imbalances in fine sediment along meandering rivers

Highlights:

- Overbank floodplain deposits often consist of easily suspended material finer than that present on the channel bed. The presentation will discuss mechanisms for net transfer of fine-grained sediment to or from a given region of the floodplain adjacent to a meandering river.
- Representing overbank deposition independently from a net local export of overbank material associated with lateral channel migration allows for the development of a model for space and time evolution of the floodplain characterized by a tendency toward a steady state volume of fine-grained material.
- The model tracks the concentration of tracer sediment through the floodplain, allowing it to be used to predict the movement of a wave of potentially contaminated fine-grained material through an alluvial channel/floodplain system.
- The model is validated on the Clark Fork River, Montana, downstream of the Butte/Anaconda copper mining complex. However, the approach is well suited to modeling the response of a floodplain to anthropogenic forcing much like what has occurred through much of the Chesapeake Bay watershed.

Dorothy Merritts
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http://www.legis.state.pa.us/cfdocs/billinfo/billinfo.cfm?syear=2007&sind=0&body=S&type=R&bn=283

Presentation Title: Anatomy of a Mill Pond: Case Studies of Dam Breaches Spanning Two Centuries

Highlights:
Low-head dams built to power mills on low-gradient Piedmont streams during the late 17th to late 19th centuries significantly altered pre-European settlement valley bottoms and led to trapping of fine sediment across original valley floors. This presentation examines the nature of the sediment stored in the reservoirs upstream of 5 mill dams and compares it to the sediment and fluvio-wetland landforms in valley bottoms prior to mill damming and widespread land-clearing. Historic records, field mapping, and surveying for these five case studies are sufficient to evaluate channel response to dam breaching and the history and rate of sediment remobilization since the time of dam breach. Dam breach dates span more than a century, providing an opportunity to examine how channels evolve in a dissected millpond reservoir. These case studies are considered in the context of current stream restoration practices.

Andrew Miller

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Presentation Title: Sources and storage of sediment in urbanizing watersheds, Maryland and Pennsylvania

Highlights:
Despite long-standing interest in downstream impacts of sediment in urbanizing watersheds, we have relatively few long-term records of sediment load and much of the available monitoring data is at least 25-30 years old. The recently renewed focus on the potential importance of stored "legacy" sediment as a component of the watershed sediment budget has generated much discussion about the benefits of stream restoration projects to mitigate the downstream effects of bank erosion. Recent studies in Pennsylvania and Maryland suggest that sediment remobilized by bank erosion represents a large fraction of the urban watershed sediment budget, but continuing floodplain and channel storage provide important sediment sinks that should not be neglected and that may be comparable in magnitude to the major sources. Furthermore upland sources may still be important, even in watersheds with high percent impervious cover. It is argued that we need to better quantify loads, residence times, relative magnitudes of different sources, and the balance between rates of sediment storage and remobilization before we can evaluate the merits of policies that favor channel modification as a remedy for downstream sediment problems.

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Presentation Title: Dirt: The Erosion of Civilizations

Highlights: http://www.ucpress.edu/books/pages/10599.php

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Presentation Title: Fish assemblages and fine sediment

Highlights:
- Fine sediment is a natural and important component of stream ecosystems
- Excessive inputs of fine sediment may significantly alter the structure and function of stream systems
- For stream fishes, the most significant effect of excessive fine sediment is during spawning
- Salmonids are extremely vulnerable to fine sediment inputs due to redd destruction
- Fine sediment may alter stream fish assemblages, resulting in the presence of tolerant species and the loss of intolerant species

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Presentation Title: The role of sediment accumulation by floodplains on riverine nutrient (P and N) retention in the Chesapeake Bay watershed.

Highlights:
- Rates of nutrient accumulation were measured as sediment accumulation on floodplains soils throughout the coastal plain of the Chesapeake Bay watershed.
- These floodplain nutrient accumulation rates typically were 24%, 59%, and 119% of their rivers' annual loads of nitrogen, phosphorus, and sediment, respectively.
- Several assumptions behind these calculations of high retention rates by floodplains are being evaluated in a new USGS study of piedmont floodplains in Difficult Run, Fairfax County, Virginia.

Milan Pavich

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Presentation Title: Chesapeake Glacioisostasy: Is There a Yo Yo, Ma?

Highlights:
The accommodation space for fine sediment in Chesapeake Bay is increasing due to an average relative sea level rise of ca. 4mm/y. At least half of that sea level rise is the result of subsidence driven by collapse of the last Laurentide glacial maximum forebulge. Stratigraphy of pre-Holocene estuarine sediments in tributary basins shows that subsidence is the dominant mode of crustal motion over the past 120ky. This information shows the need for more detailed investigation of spatial variability of subsidence over the Chesapeake tidal tributaries in order to predict its impact on shoreline erosion, channel geometry, and the fate of fine sediment.

Jonathan Phillips

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Title: Non-equilibrium Sediment Flux in Coastal Plain Rivers

Highlights:
Steady-state equilibrium sediment flux, whereby sediment yield roughly balances sediment production within a watershed, is rare and transient in coastal plain rivers, as shown via examples from the south Atlantic and Gulf of Mexico. One implication is that, in many rivers, much fluvial sediment is stored within or upstream of the fluvial/estuarine transition zone and is not delivered to coastal environments. This has important ramifications for management of sediment and sediment-associated pollutants in estuaries, and for the fate and storage of fluvial sediments. The prevalence of non-equilibrium fluvial dynamics also has implications with respect to the models, conceptual frameworks, and analytical techniques applied to studies of fluvial sediment sources, storage, and sinks. Finally, while non-equilibrium in general is not uncommon, the specific present sediment flux and storage regimes of Atlantic and Gulf coastal plain rivers are largely contingent on Quaternary sea level histories. Thus, sensitivity to climate-driven sea level change is an important question.

Jim Pizzuto

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Presentation Title: Geomorphic Evolution and Multi-Decadal Fine-Grained Sediment Budget of a 4th Order Tributary to the Chesapeake Bay: Guiding Principles and Lessons Learned

Highlights:

- Significant geomorphic evolution of rivers and floodplains occurs on timescales of 1000 years or more at current rates and processes
- Storage on floodplains is an important component of the sediment budget, even though the geomorphic evolution of floodplains is nearly vanishingly slow.
- Fine-grained sediment is also stored within the channel perimeter in the bed and in slack water environments created by bank irregularities and large woody debris. The residence time of sediment in these environments is typically a few years, but some sediment is stored for many decades. As a result, contaminants stored with these sediments may not be flushed from the channel for timescales of centuries.
- Bank erosion and tributaries are the dominant sources of fine-grained sediment to higher order streams.
- Bank erosion rates increased by ~ 2x during the middle of the 20th century as a result of the loss of mill dams in our study area.
- The geomorphic evolution of the study area does not follow any well-established conceptual model as a result of its recent history of anthropogenic influence and pervasive control by bedrock on fluvial processes.

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Presentation Title: Using environmental radio-nuclides to study stream bank erosion

Highlights:

- Determining sediment source areas in the watershed is a key component for designing management strategies to reduce sediment and chemical loads
- Potential sediment sources in a watershed can be characterized (fingerprinted) using environmental radio nuclides, chemical, and/or physical properties
- The objective of this study was to show the use Cesium-137 to determine the relative importance of stream bank erosion.
- These studies (along with many that are published) show the potential for using Cs-137 to determine the relative importance of different sediment sources in a watershed.

Tom Schueler

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Presentation Title: Sediment Sources in Urban and Urbanizing Watersheds in the Chesapeake Bay and Emerging Management Strategies to Reduce Them

Highlights:
This presentation will review the current science on the sources of sediment from urban and urbanizing watersheds in the Chesapeake Bay, with a focus on the wash-off of sediment from impervious areas, erosion from construction sites, and sediments derived from urban stream channel erosion. In addition, the presentation will focus on research indicating that the importance of the "missing sediment load" delivered by larger sized sediment fractions in urban watersheds. The potential scope of future urban sediment problems will be described using recent growth forecasts for communities across the watershed. The presentation will also present a critique of current stormwater management, erosion and sediment control and stream repair strategies in the State of Maryland (and elsewhere in the Bay) and indicate how upcoming changes to permits, policies, regulations and design manuals could greatly reduce the sediment loads contributed from urban watersheds.

Gary Shenk

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Presentation Title: Sediment simulation in the Chesapeake Bay Program's Watershed Model.

Highlights:

- Use of the watershed model in management decisions.
- Methods of Sediment simulation
- Sources and types of data used to calibrate the model

Automated Calibration methods.

Katherine Skalak

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Presentation Title: Fine-grained channel margin deposits and their implications for centennial mercury cycling in a gravel bed river

Highlights:

- The sediment budget for South River led to the discovery of a unique in-channel depositional environment, fine-grained channel margin (FGCM) deposits
- Presentation of fine-grained channel margin deposits
  - Occurrence, distribution, characteristics (grain size, organics, mercury)
  - Controls (obstructions, low velocity, large woody debris)
  - Volume distributions and significance
  - Residence times and significance
  - Importance of FGCM deposits to suspended sediment flux and sediment budgets
  - Ecological significance
- Role of FGCM deposits in determining historic mercury loadings in South River
  - High concentrations (> 80 ppm) indicate the release period, lower concentrations (<15 ppm) indicate post-release period
  - FGCM deposits are a record of mercury concentrations associated with suspended sediment and can be used to determine loading rates

Presentation of a preliminary centennial particle associated mercury budget, which is based on the components from the sediment budget and concentrations from FGCM deposits.

Joel Snodgrass

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Presentation Title: Impacts of Fine Sediments on the Biota of Aquatic Habitats: Pollutant Sources and Habitat Modification

Highlights:
The biological effects of fine sediments are set in a context of spatial relationship of aquatic habitats within the Chesapeake Bay drainage. These spatial relationships control the characteristics and amounts of fine sediments that biotic communities are exposed to. Because pollutants are often associated with fine sediments, exposure to fine sediments accumulated in aquatic habitats can have toxic effects on biota. Fine sediments may also degrade aquatic habitats through the modification of habitat structure. In this talk I will review relationships between fine sediments, associated pollutants, and land use. I will also discuss the effects of fine sediments on aquatic biota with a particular emphasis on amphibians.

Richard Vogel

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Presentation Title: How Effective is the Effective Discharge?

Highlights:
The concept of 'effective discharge' is widely used for stream restoration and sediment management. Recent research has shown that the fraction of the long term sediment load carried by discharges below the effective discharge varies widely from one watershed to the next. Other indices such as the 'half load discharge' may provide more relevant information regarding the relationship between sediment loads and river discharge and regarding the ability of a river to carry sediment. This presentation will provide a review of these concepts. In addition the relationship between river discharge and sediment behavior will be summarized for rivers across the U.S. and comparisons among the various discharge indices and their ability to describe sediment behavior will be provided.

Appendix B: Synthesis session questions and responses

Responses to the two questions put forward to workshop attendees indicated continued concern regarding the extent of sediment information necessary to effectively target sediment problems and prescribe management actions in the Chesapeake Bay watershed. Despite the advances in the previous five years, the responses point to a continued demand for clarification of sediment culprits and treatments other than dams that have the capacity to alter current watershed sediment yields trends. The expanded and more carefully defined role of sediment budgets in watershed management was highlighted by some as a means to advance the pursuit of sediment load reductions. However, the connections between the nontidal sediment budgets and conditions in the Bay estuary need to be more clearly described. No single best management practice (BMP) was identified as a solution to current sediment management problems. BMP monitoring was recommended as a means to enhance the understanding of watershed sediment processes and the relations to investments intended to reduce sediment loads in the Chesapeake Bay.

Response to the synthesis questions that are presented here were initially assembled with input from attendees during the breaks and final session of the workshop. Minor edits were added to the initial set of responses for clarification. Several additional responses were framed after the workshop in response to peer review by the Sediment Workgroup members that pointed out omitted comments put forward during the final session of the workshop.

Question 1: What are the key knowledge gaps in watershed sediment modeling, monitoring, and assessment?

1. Long term comprehensive monitoring is inadequate, including the data collection that tracks hydrologic and suspended sediment trends.

2. The long term effects of fine sediment on nontidal aquatic ecosystems are not well quantified.

3. The meaning of “effective discharge” to fine sediment management is unclear.

4. The delivery of sediment from uplands to valleys and from valleys to the Bay may be misrepresented in many basins.

5. The relative influence of watershed sediment on the Bay is unclear.

6. The relative influence of sediment to other stresses in nontidal streams and the Bay has not been quantified.

7. The relative ranking of watershed sediment sources has not been quantified in most systems.

8. The range of flows we should be managing to address sediment loads in large rivers is unclear.

Question 2: What are the most effective BMPs for reducing fine sediment loads to the Chesapeake Bay?

1. Watershed scale sediment load trends can not be determined in a typical political cycle.

2. History (human, geologic, geomorphic) may not matter as much as good monitoring data for management targeting.

3. Hillslopes provide historic and contemporary watershed sediment sources. Valleys regulate the sediment delivery by storing sediment over varied time periods. Neither hillslopes nor valleys exhibit the same sediment flux trends in all locations.

4. The implications of valley modifications intended to change sediment delivery trends need to be assessed in different watersheds.

5. Dams can influence the delivery of sediment to large rivers and the Bay estuary.

6. Sediment budgets provide information on locations and magnitude of sediment contributions, but may not offer enough information to guide BMP selection.

7. Sediment BMPs need to continue to be developed, monitored, and evaluated to assess performance of the investments as new information on the sources and fate of fine sediment become available.

8. Presenting BMP performance monitoring results in the context of watershed sediment budgets may have the capacity to enhance the ability to target watershed management investments.