Appendix A Annotated Bibliography

Allmendinger, N.E., Pizzuto, J.E., Moglen, G.E., & Lewicki, M. (2007). A sediment budget for urbanizing watershed, 1951-1996, Montgomery County, Maryland, U.S.A. *Journal of the American Water Resources Association,* 43 (6), 1483-1498.

The authors, a geomorphologist at Otak, Inc. and researchers at the University of Delaware, the University of Maryland, and the USDA Forest Service, used a variety of indirect and stratigraphic data to assess the sediment budget for the Good Hope Tributary watershed in Montgomery County, Maryland. Regression equations determined that channel cross-sectional area was correlated to development within the watershed. Results of their investigation indicated that upland erosion, channel enlargement, and floodplain storage are all significant components of the sediment budget and that the remobilized “legacy” sediments contribute less than 20% and are not a dominant component of sediment yield.

Anderson Jr., W.P., Anderson, J.L., Thaxton, C.S., & Babyak, C.M. (2010). Changes in stream temperatures in response to restoration of groundwater discharge and solar heating in a culverted, urban stream. *Journal of Hydrology,* 393, 309-320.

The authors, researchers at Appalachian State University and the University of South Carolina, used a Monte Carlo thermal mixing model to predict the effect of removing a 700-m-long culvert. The model incorporated cooling effect from restored baseflow and surface-heat exchange effects. Modeled temperatures suggest a decrease in summer stream temperatures in a hypothetically restored stream with removal of a long culvert.

Andrews, D.M., Barton, C.D., Kolka, R.K., Rhoades, C.C., & Dattilo, A.J. (2011). Soil and water characteristics in restored canebrake and forest riparian zones. *Journal of the American Water Resources Association,* 47 (4), 772-784.

The authors, a botanist at the Tennessee Valley Authority and researchers at Pennsylvania State University, the University of Kentucky, and the USDA Forest Service, evaluated the use of giant cane in riparian restoration to compare water quality and soil attributes between restored cane and forest communities. Experimental plots, some planted entirely with cane, some with a mixture of forest hardwood species, and some undisturbed, were combined with stream and groundwater sampling to determine water quality improvement. Significant differences in groundwater DO, NO_3-N, NH_4-N, and Mn between the two vegetation types seems to indicate that redox conditions were not similar. The authors concluded that additional monitoring is needed but that both vegetative communities are transitioning toward the undisturbed plots.

Baldigo, B.P., Ernst, A.G., Warren, D.R., & Miller, S.J. (2010). Variable responses of fish assemblages, habitat, and stability to natural-channel-design restoration in Catskill Mountain streams. *Transactions of the American Fisheries Society,* 139, 449-467.

The authors, researchers at the USGS, Cornell University, and the New York City Department of Environmental Protection, conducted fish and habitat surveys at stream sites in the Catskill Mountains of New York before and after restoration using natural-channel-design (NCD) to evaluate the effects of NCD on fish assemblages, habitat, and bank stability. They researchers noticed significant increases in community richness, diversity, species or biomass equitability, and total biomass in most of the restored reaches. They also found bank stability, stream habitat, and trout habitat suitability indices (HIS) improved at most of the restored reaches.

Baldwin, A.H. (2007). *Urban Stream Restoration Best Management Practice* (Recommendations for Formal Approval by the Nutrient Subcommittee's Tributary Strategy and Urban Stormwater Workgroups). Chesapeake Bay Program: Author.

The author, a researcher at the University of Maryland, performed a literature review to evaluate the effectiveness of stream restoration as a Best Management Practice and propose recommended removal efficiencies for use in the Chesapeake Bay Program's Phase 5.0 Watershed Model.

Beechie, T.J., Sear, D.A., Olden, J.D., Pess, G.R., Buffington, J.M., Moir, H., Roni, P., & Pollock, M.M. (2010). Process-based principles for restoring river ecosystems. *BioScience,* 60 (3), 209-222.

The authors, research fish biologists at NOAA, a watershed program manager, research geomorphologists at the US Forest Service and the Macaulay Institute, and researchers at the University of Southampton and University of Washington, outline and illustrate four principles for process-based stream restoration to ensure sustainable actions in terms of the physical, chemical, and biological processes of streams. The authors discuss the key components of process-based restoration and give examples for a variety of applications.

Berg, J. (Ed.). (2009). A new paradigm for water resources management. *Water Resources Impact,* 11 (5).

This issue, containing articles from several researchers from a variety of backgrounds, discusses the current situation of streams, suggesting that colonial land clearing practices changed stream valley morphologies from broad, shallow systems to narrow, deep channels. Case studies of these stream morphologies are discussed along with potential approaches for effective and efficient restoration and management.

Bergmann, K. Fava, J., & Clauser, A. (2011). *Using a bank erosion and deposition protocol to determine sediment load reductions achieved for streambank restorations.* Poster session presented at the Delaware Estuary Science and Environmental Summit, Cape May, NJ.

The authors of this poster, researchers from the Brandywine Valley Association and Clauser Environmental, used bank pins to measure erosion/deposition in three study reaches to determine efficiency of potential restorations. The authors found highest erosion/deposition values in the unstabilized, proposed restoration reach.

Bernhardt, E.S., Palmer, M.A., Allan, J.D., Alexander, G., Barnas, K., Brooks, S., Carr, J., Clayton, S., Dahm, C., Follstad-Shah, J., Galat, D., Gloss, S., Goodwin, P., Hart, D., Hassett, B., Jenkinson, R., Katz, S., Kondolf, G.M., Lake, P.S., Lave, R., Meyer, J.L., O'Donnell, T.K., Pagano, L., Powell, B., & Sudduth, E. (2005). Synthesizing U.S. river restoration efforts. *Science,* 308, 636-637.

The authors, researchers from several universities and government agencies, discussed the results of evaluating more than 37,000 river restoration projects in the U.S. as part of the National River Restoration Science Synthesis (NRRSS) database. The NRRSS database separated projects into 13 categories and classified each according to its stated restoration goal. Restoration efforts and costs varied greatly across geographic regions. The authors concluded that a comprehensive assessment of restoration progress within the U.S. is not feasible and that more monitoring is needed to determine the effectiveness of stream restoration projects.

Brush, G.S. (2008). Historical land use, nitrogen, and coastal eutrophication: a paleoecological perspective. *Estuaries and Coasts,* 32 (1), 18-28.

The author, a researcher at Johns Hopkins University, used sediment core analysis throughout the Chesapeake Bay watershed to establish that denitrification opportunities have decreased and nitrogen sources have increased over the past 300 years. This has led to an increasingly eutrophic and anoxic estuary. The author offers some options for reducing nitrogen from entering the estuary, including increasing opportunities for denitrification, retrofitting septic systems, and restoring wetlands.

Bukaveckas, P.A. (2007). Effects of channel restoration on water velocity, transient storage, and nutrient uptake in a channelized stream. *Environmental Science & Technology,* 41 (5), 1570-1576.

The author, a researcher at Virginia Commonwealth University, evaluated the effects of restoration on a 1-km segment of Wilson Creek in Kentucky by measuring water velocity, transient storage, and nutrient uptake in both channelized (unrestored) sections and naturalized (restored) sections. Injection experiments were performed in both study reaches, resulting in a 50% increase in median travel time and significantly higher first-order uptake rate coefficients for N and P in the restored section. The author suggests that decreased velocities and a longer, meandering channel enhances nutrient uptake in restored streams as opposed to channelized streams.

Cadenasso, M.L., Pickett, S.T.A., Groffman, P.M., Band, L.E., Brush, G.S., Galvin, M.F., Grove, J.M., Hagar, G., Marshall, V., McGrath, B.P., O'Neil-Dunne, J.P.M., Stack, W.P., & Troy, A.R. (2008). Exchanges across land-water-scape boundaries in urban systems. *Annals of the New York Academy of Sciences,* 1134, 213-232.

The authors, researchers at the University of California-Davis; the Cary Institute of Ecosystem Studies; the University of North Carolina; Johns Hopkins University; the Maryland Department of Natural Resources; the USDA Forest Service; the Parks and People Foundation in Baltimore;

Columbia University; Parsons, The New School for Design; the University of Vermont; and the Baltimore City Department of Public Works, examined two urban restoration projects aimed at reducing nitrate pollution. The authors present five types of strategies to enhance nitrogen storage in urban landscapes, focusing on biogeophysical strategies such as watershed alteration and stream restoration.

Craig, L.S., Palmer, M.A., Richardson, D.C., Filoso, S., Bernhardt, E.S., Bledsoe, B.P., Doyle, M.W., Groffman, P.M., Hassett, B.A., Kaushal, S.S., Mayer, P.M., Smith, S.M., & Wilcock, P.R. (2008). Stream restoration strategies for reducing river nitrogen loads. *Frontiers in Ecology and the Environment,* 6.

The authors, researchers from several universities, government agencies, and a non-profit research center, discuss a framework for prioritizing restoration sites. They suggest that small streams with larger nitrogen loads delivered during low to moderate flows offer the greatest opportunity for nitrogen removal. In their discussion, they use examples from the Chesapeake Bay watershed.

Doheny, E.J., Dillow, J.J.A., Mayer, P.M., & Striz, E.A. (2012). *Geomorphic Responses to Stream Channel Restoration at Minebank Run, Baltimore County, Maryland, 2002-08* (Scientific Investigations Report 2012-5012). Reston, VA: U.S. Geological Survey.

The authors, researchers at the USGS and the USEPA, collected data prior to and after restoration of Minebank Run to assess geomorphic characteristics and geomorphic changes over time. Among their findings, over six years of monitoring, the stream is maintaining an overall slope of the channel bed and water surface, on average, despite changes in location, distribution, and frequency of riffles, pools, and runs. Comparing pre and post restoration data suggests reduction of lateral erosion. They also found a relationship between channel geometry and discharge.

Doyle, M.W., & Ensign, S.H. (2009). Alternative reference frames in river system science. *Bioscience,* 59 (6), 499-510.

The authors, researchers at North Carolina at Chapel Hill, apply alternative reference frames on river systems. They illustrate the use of alternative reference frames compared to traditional methods using the following examples: sediment transport, fish migration, and river biogeochemistry. The researchers demonstrate how using alternative or non-intuitive reference frames can facilitate novel research questions and observations, potentially triggering new research trajectories.

Doyle, M.W., Stanley, E.H., & Harbor, J.M. (2003). Hydrogeomorphic controls on phosphorus retention in streams. *Water Resources Research,* 39 (6), 1-17.

The authors, researches at the University of North Carolina at Chapel Hill; the University of Wisconsin; and Purdue University, examined the influence of biochemical uptake process and hydrogeomorphology on molybdate reactive phosphorus (MRP) retention within a stream reach. The researchers focused on a stream reach that was undergoing channel adjustment in response to a downstream dam removal. They found that uptake rates should have a stronger influence on reach-scale MRP retention than changing channel morphology or hydrology.

Doyle, M.W., Stanley, E.H., Strayer, D.L., Jacobson, R.B., & Schmidt, J.C. (2005). Effective discharge analysis of ecological processes in streams. *Water Resources Research,* 41, 1-16.

The authors, researchers at the University of North Carolina at Chapel Hill; University of Wisconsin; Institute of Ecosystem Studies; the Columbia Environmental Research Center; and Utah State University, used the concept of effective discharge to analyze the interaction between frequency and magnitude of discharge events on selected stream ecological processes. Their results indicate that a range of discharges is important for different ecological processes in a stream. The researchers suggest four types of ecological response to discharge variability: discharge as a transport mechanism, regulator of habitat, process modulator, and disturbance.

Endreny, T.A., & Soulman, M.M. (2011). Hydraulic analysis of river training cross-vanes as part of post-restoration monitoring. *Hydrology and Earth System Sciences,* 15, 2119-2126.

The authors, researchers at State University of New York College of Environmental Science and Forestry, conducted post-restoration monitoring and simulation analysis for a Natural Channel Design (NCD) restoration project completed in 2002 in the Catskill Mountains, New York. The authors found that processing monitoring data with hydraulic analysis software provided better information that could help extend project restoration goals and structure stability.

Ensign, S.H., & Doyle, M.W. (2005). In-channel transient storage and associated nutrient retention: evidence from experimental manipulations. *Limnology and Oceanography,* 50 (6), 1740-1751.

The authors, researchers at the University of North Carolina at Chapel Hill, used experimental channel manipulation to examine the effect of in-channel flow obstructions on transient storage and nutrient uptake. In their study areas, they found that in-channel transient storage influenced nutrient uptake in a blackwater stream; however similar results could not be confirmed in an agricultural stream.

Filoso, S., & Palmer, M.A. (2011). Assessing stream restoration effectiveness at reducing nitrogen export to downstream waters. *Ecological Applications,* 21 (6), 1989-2006.

The authors, researchers at the University of Maryland, evaluated whether stream restoration projects in the Chesapeake Bay region is effective at reducing nitrogen transport to downstream waters. They found that in order for stream restoration to be most effective in reducing nitrogen fluxes transported downstream, strategic restoration designs should be used and include features that enhance the processing and retention of different forms of nitrogen for a wide range of flow conditions.

FISRWG. (1998). ***Stream Corridor Restoration: Principles, Processes, and Practices*** **(GPO Item No. 0120-A). Federal Interagency Stream Restoration Working Group.**

The authors, researchers from various federal agencies, collaborated to produce this technical reference on stream corridor restoration. The document reviews the elements of restoration, and provides a framework to plan restoration actions, including no action or passive approaches, partial intervention for assisted recovery, and substantial intervention for managed recovery. The information in the document can be applied to urban or rural setting, and applies to a range of stream types.

Fraley, L.M., Miller, A.J., & Welty, C. (2009). Contribution of in-channel processes to sediment yield of an urbanizing watershed. ***Journal of the American Water Resources Association,*** **45 (3), 748-766.**

The authors, researchers at the Center for Watershed Protection and the University of Maryland, conducted a study to monitor sediment transport and storage in a tributary of the Schuylkill River in Pennsylvania. They found that bank erosion in their study reach contributed an estimated 43 percent of the suspended sediment load. Although bank erosion is a significant source of sediment, bed sediment storage and potential for remobilization are also important components of the sediment budget.

Harrison, M.D., Groffman, P.M., Mayer, P.M., & Kaushal, S.S. (2012). Microbial biomass and activity in geomorphic features in forested and urban restored and degraded streams. ***Ecological Engineering,*** **38, 1-10.**

The authors, researchers at the University of Maryland, the Cary Institute of Ecosystem Studies, NOAA, and the US EPA, measured sediment denitrification potential (DEA), net nitrification, methanogenesis, and microbial variables in various stream features and in several different stream settings. They found that DEA was higher in organic debris dams and in forest streams, but their results were not statistically significant. They also found that DEA was related to microbial biomass nitrogen and sediment organic matter, and also methanogenesis was active in all stream geomorphic features. Overall, the results suggest that in-stream geomorphic features in urban restored and degraded sites have the potential to function as nitrogen sinks.

Harrison, M.D., Groffman, P.M., Mayer, P.M., Kaushal, S.S., & Newcomer, T.A. (2011). Denitrification in alluvial wetlands in an urban landscape. ***Journal of Environmental Quality,*** **40, 634-646.**

The authors, researchers at the University of Maryland, the Cary Institute of Ecosystem Studies, and the US EPA, measured denitrification rates to compare the variation and magnitude in urban and forested wetlands in the Baltimore metropolitan area. They found that mean denitrification rates did not differ among wetland types, suggesting that urban wetlands have the potential to reduce nitrate in urban watersheds. Their findings also suggest that wetlands are sinks for nitrate year round.

Hartranft, J.L., Merritts, D.J., Walter, R.C., & Rahnis, M. (2011). The Big Spring Run restoration experiment: policy, geomorphology, and aquatic ecosystems in the Big Spring Run watershed, Lancaster County, PA. *Sustain,* 24, 24-30.

The authors, researchers at the Pennsylvania Department of Environmental Protection and Franklin and Marshall College, are investigating whether an anastomosing channel valley bottom floodplain systems can effectively restore critical zone function at Big Springs Run in Pennsylvania. Their approach includes: developing significant metrics to assess critical zone process; developing, implementing, and monitoring a restoration project that diagnoses the causes of impairments; and evaluate the implications of this restoration strategy. At the time of the paper, the researchers had completed three years of pre-restoration monitoring and were anticipating the commencement of restoration activities.

Henshaw, P.C. (1999). Restabilization of stream channels in urban watersheds. *Proceedings of the American Water Resources Association Annual Water Resources Conference on "Watershed Management to Protect Declining Species,"* Seattle, WA.

The author, a researcher at Northwest Hydraulic Consultants, used a variety of field and historical data from streams in urban and urbanizing watersheds to determine the rate and extent of change in channel form over time. The researcher found that restabilization of urbanized stream channels usually occurs in highly urbanized watersheds, and most stabilize within 10 to 20 years of constant land cover in the watershed. The possibility that a channel will restabilize depends mainly on hydrologic and geomorphic characteristics of the channel and its watershed, rather than the magnitude or rate of development.

Hill, T., Kulz, E., Munoz, B., & Dorney, J. (2011). *Compensatory stream and wetland mitigation in North Carolina: an evaluation of regulatory success.* North Carolina Department of Environment and Natural Resources: Author.

The authors, researchers at the North Carolina Department of Environment and Natural Resources and RTI International, investigated regulatory success rates of wetland and stream mitigation projects in North Carolina. They collected information to compare current statewide mitigation project conditions with regulatory requirements during 2007-2009 by reviewing files and directly observing sites. Overall, the researchers found that mitigation success rates, based on whether the mitigation site met the regulatory requirements for the project that were in place at the time of construction, were estimated at 74 percent for wetlands, and 75 percent for streams in North Carolina. They also found that wetland mitigation success rate has increased since the mid 1990's. In addition, the researchers performed a variety of statistical analyses to evaluate the success of mitigation based on various aspects including mitigation provider, method, project location, age, and size.

Hillman, M., & Brierly, G. (2005). A critical review of catchment-scale stream rehabilitation programmes. *Progress in Physical Geography,* 29 (1), 50-70.

The authors, researchers from Macquarie University and the University of Auckland, performed a literature review and examined case studies of contemporary catchment-wide programs. They found the following challenges in programs: generating an authentic and functional biophysical vision at the catchment scale, developing a proactive adaptive management approach, achieving genuine community participation, and integrating biophysical and social factors in a transdisciplinary framework. They suggest addressing issues of scale, natural variability and complexity to meet those challenges.

Johnson, P.A., Tereska, R.L., & Brown, E.R. (2002). Using technical adaptive management to improve design guidelines for urban instream structures. *Journal of the American Water Resources Association,* 38 (4), 1143-1152.

The authors, a researcher from Penn State University and engineers from Erdman, Anthony, Associates, Inc. and the Central Federal Lands Highway Division of the FHA, used technical adaptive management to update guidelines for effective use, design, and construction of instream structures. They note that monitoring, evaluation of data, and communication of results are crucial components of the adaptive management process to prevent future failures. They used three case studies of urban streams in Maryland to provide data for updating and improving the Maryland guidelines.

Kaushal, S.S., Groffman, P.M., Mayer, P.M., Striz, E., & Gold, A.J. (2008). Effects of stream restoration on denitrification in an urbanizing watershed. *Ecological Applications,* 18 (3), 789-804.

The authors, researchers at the University of Maryland, the Institute of Ecosystem Studies, the U.S. EPA, and the University of Rhode Island, used in situ measurements of ^{15}N tracer additions to determine if hydrologic reconnection of a stream to its floodplain could increase rates of denitrification in an urban stream. Mean rates of denitrification were significantly greater in restored reaches and restored riparian areas with hydrologically connected stream banks had higher rates of denitrification than similarly restored riparian areas with high, nonconnected banks. Stream restoration designed to reconnect stream channels and floodplains can increase denitrification rates but there can be substantial variability in the efficacy of restoration designs.

Klocker, C.A., Kaushal, S.S., Groffman, P.M., Mayer, P.M., & Morgan, R.P. (2009). Nitrogen uptake and denitrification in restored and unrestored streams in urban Maryland, USA. *Aquatic Sciences,* 71, 411-424.

The authors, researchers at the University of Maryland, the Cary Institute of Ecosystem Studies, and the US EPA National Risk Management Research Lab, analyzed nitrogen processes to quantify nitrate uptake in restored and unrestored streams in Baltimore, Maryland. They found that denitrification potential in sediments varied across streams, and nitrate uptake length appeared to be correlated to surface water velocity. Their results suggest restoration approaches that increase hydrologic “connectivity” with hyporheic sediments and increase hydrologic residence time may influence denitrification rates in stream reaches.

Kroes, D.E., & Hupp, C.R. (2010). The effect of channelization on floodplain sediment deposition and subsidence along the Pocomoke River, Maryland. *Journal of the American Water Resources Association,* 46 (4), 686-699.

The authors, an ecologist at the USGS and a botanist at the USGS, studied floodplain sediment dynamics at six sites along the Pocomoke River. They assessed the effects of channelization on sediment deposition, storage, and subsidence along the stream. They found that channelization resulted in limited sediment retention and an increase in sediment deposition in down-stream reaches. In addition, drainage of floodplains resulted in subsidence and release of stored carbon.

Lakly, M.B., & McArthur, J.V. (2000). Macroinvertebrate recovery of a post-thermal stream: habitat structure and biotic function. *Ecological Engineering,* 15, 87-100.

The authors, researchers at the University of Georgia and the Savannah River Ecology Laboratory, conducted a study of macroinvertebrate faunal assemblages, organic matter availability and in stream structural complexity in three systems to determine the current state of recovery of a post-thermal stream. They found that the abundance and diversity of the lower foodchain community has recovered since termination of thermal flows in 1988. They also found that the biotic communities remain structurally and functionally distinct as a result of the thermal disturbance.

Land Studies. (2005). *Stream bank erosion as a source of pollution: research report*. Author.

The author, Land Studies, performed a literature review of stream projects in the Lower Susquehanna watershed in Pennsylvania. Based on the projects they reviewed, they have found that stream bank erosion is a significant source of nonpoint sediment and nutrient pollution. They also mention that legacy sediments could potentially be a significant contributor of sediment and nutrients.

Lautz, L.K., & Fanelli, R.M. (2008). Seasonal biogeochemical hotspots in the streambed around restoration structures. *Biogeochemistry,* 91, 85-104.

The authors, researchers at the State University of New York College of Environmental Science and Forestry, examined the seasonal patterns of water and solute fluxes through a streambed near a stream restoration structure. They found that regardless of season of the year, anoxic zones were primarily located upstream of the structure, in a low-velocity pool, and oxic zones were typically located downstream of the structure in a turbulent riffle. They suggest that restoration structures that span the full channel, such as those used in natural channel design restoration, will influence the biogeochemical processing in the streambed.

Mayer, P.M., Groffman, P.M., Striz, E.A., & Kaushal, S.S. (2010). Nitrogen dynamics at the groundwater-surface water interface of a degraded urban stream. *Journal of Environmental Quality,* 39, 810-823.

The authors, researchers at the USEPA, the Cary Institute of Ecosystem Studies, and the University of Maryland, investigated groundwater ecosystem in an urban degraded stream near Baltimore, Maryland in the Chesapeake Bay watershed. Their objectives were to identify spatial and temporal extent of chemical, microbial, and hydrological factors that influence denitrification. Their results suggested that denitrification and removal of nitrate in groundwater were limited by dissolved organic carbon (DOC) availability. They observed that groundwater nitrate was highest when groundwater levels were highest, corresponding to high oxidation-reduction potential (ORP), suggesting high groundwater-surface water exchange.

McClurg, S.E., Petty, J.T., Mazik, P.M., & Clayton, J.L. (2007). Stream ecosystem response to limestone treatment in acid impacted watersheds of the Allegheny Plateau. *Ecological Applications,* 17 (4), 1087-1104.

The authors, researchers at West Virginia University and the West Virginia Division of Natural Resources, sampled stream chemistry in addition to collecting physical and biological data in three stream types, acidic, acidic streams treated with limestone, and reference streams in West Virginia. Their objectives were to assess acid-precipitation remediation programs in streams, identify attributes that could not be fully restored, and quantify temporal trends in ecosystem recovery. They did not observe temporal trends in recovery, and their results indicated that the application of limestone sand to acidic streams was effective in recovering some stream characteristics; however, recovery was less successful for others.

Merritts, D., Walter, R., & Rahnis, M.A. (2010). *Sediment and nutrient loads from stream corridor erosion along breached millponds.* Franklin & Marshall College: Author*.*

The authors, researchers at Franklin and Marshall College, assessed sediment production rates, nutrient contents, and erosion mechanisms of stream corridor sediments in the Chesapeake Bay watershed. They found that stream corridor erosion, especially stream bank erosion, is a major contributor to the suspended sediment and particulate-phosphorus loads, in addition to a substantial source of nitrogen loads.

Merritts, D., Walter, R., Rahnis, M., Hartranft, J., Cox, S., Gellis A., Potter, N., Hilgartner, W., Langland, M., Manion, L., Lippincott, S. S., Rehman, Z., Scheid, C., Kratz, L., Shilling, A., Jenschke, M., Datin, K., Cranmer, E., Reed, A., Matuszewski, D., Voli, M., Ohlson, E., Neugebauer, A., Ahamed, A., Neal, C., Winter, A., & Becker, S. (2011) *Philosophical Transactions of the Royal Society A,* 369, 976-1009.

The authors, researchers at Franklin and Marshall College, the PA Department of Environmental Protection, the USGS, Dickinson College, and Johns Hopkins University, used LIDAR, field data, and case studies of breached dams in rural and urban watersheds to determine whether stream incision, bank erosion, and increased sediment load is caused by land use changes. In the case of valleys impacted by milldams, modern incised streams represent a transient response to base-level forcing and major changes in historic land use.

Miller, J.R., & Kochel, R.C. (2010). Assessment of channel dynamics, in-stream structures and post-project channel adjustments in North Carolina and its implications to effective stream restoration. *Environmental Earth Sciences,* 59, 1681-1692.

The authors, researchers at Western Carolina University and Bucknell University, analyzed data collected during site assessments and monitoring of 26 restoration sites in North Carolina. Their results suggest that the channel reconfiguration of reaches in a state of equilibrium, which do not exhibit excessive erosion or deposition along highly dynamic rivers is currently problematic. They propose use of a conceptual framework based on geomorphic parameters to assess the likelihood of a project's success.

Montana Department of Environmental Quality. (2009). *Shields River Watershed Water Quality Planning Framework and Sediment TMDLs* (Y02-TMDL-01A). Helena, MT: Author.

The author, the Montana Department of Environmental Quality, used the BEHI method to estimate sediment delivery from stream banks. The method predicts stream erosion rate to sampled stream banks, creating an extrapolation factor from the results, and applying this extrapolation factor to the total length of the streams. The method was used in the Shields watershed to predict bank erosion rates based on BEHI ratings developed from collected field data.

Naiman, R.J., & Melillo, J.M. (1984). Nitrogen budget of a subarctic stream altered by beaver (Castor canadensis). *Oecologia,* 62, 150-155.

The authors, researchers at Woods Hole Oceanographic Institution and the Marine biological Laboratory, measured rates of nitrogen dynamics to construct a nitrogen budget and quantify the influence of beavers on stream eco-systems. They found that changes after impoundment include reduction in allochthonous nitrogen and an increase in nitrogen fixation by sediment microbes. In general, the modified section accumulated a significant amount of nitrogen than before alteration.

Niezgoda, S.L., & Johnson, P.A. (2007). Case study in cost-based risk assessment for selecting a stream restoration design method for a channel relocation project. *Journal of Hydraulic Engineering,* 133 (5), 468-481.

The authors, researchers at the University of Wyoming and Penn State University, used a case study of a stream in central Pennsylvania to illustrate a cost-based risk assessment method to address complexities and uncertainties involved with stream restoration design. During the case study, the researchers found that uncertainty and risk was reduced using the risk-based method by detecting design deficiencies that the initial design overlooked.

Northington, R.M., & Hershey, A.E. (2006). Effects of stream restoration and wastewater treatment plant effluent on fish communities in urban streams. *Freshwater Biology,* 51, 1959-1973.

The authors, researchers at the University of North Carolina at Greensboro, assessed fish community characteristics, resource availability and resource use in three headwater urban streams in North Carolina. The three site types the researchers looked at were a restored urban, an unrestored urban, and a forested sited located downstream of urbanization, and that was impacted by effluent from a wastewater treatment plant (WWTP). At sites sewage-influence sites, the researchers found that the WWTP affected isotope signatures in the biota and they observed lower richness and abundance of fish. They also observed that the restored sites tended to have higher fish richness and greater abundances, compared to unrestored sites. In addition, the researchers conducted additional isotope analysis to determine terrestrial influences on fish.

Northington, R.M., Benfield, E.F., Schoenholtz, S.H., Timpano, A.J., Webster, J.R., & Zipper, C. (2011). An assessment of structural attributes and ecosystem function in restored Virginia coalfield streams. *Hydrobiologia,* 671, 51-63.

The authors, researchers at Virginia Polytechnic Institute and State University, assessed restoration on stream sections affected by surface coal mining activities by evaluating structure and function ecosystem variables in restored and unrestored sections. They observed that in streams affected by mining, macroinvertebrate assemblages in streams were considered stressed and habitat ratings varied between fair and optimal. They found no site differences for any physicochemical or functional variables. In unrestored streams, invertebrate community metric scores tended to be higher.

Orzetti, L.L., Jones, R.C., & Murphy, R.F. (2010). Stream condition in Piedmont streams with restored riparian buffers in the Chesapeake Bay watershed. *Journal of the American Water Resources Association,* 46 (3), 473-485.

The authors, researchers at Ecosystem Solutions and George Mason University, evaluated the efficacy of restored forest riparian buffers along streams in the Chesapeake Bay watershed by examining habitat, water quality variables, and benthic macroinvertebrate community metrics. They found that in general, habitat, water quality, and benthic macroinvertebrate metrics improved with age of restored buffer, with noticeable improvements within 5 to 10 years following restoration.

Palmer, M. (2009). Western Chesapeake Coastal Plain stream restoration targeting. (319(h) program report). *Chesapeake Biological Laboratory – UMCES*.

The author, a researcher at the Chesapeake Biological Laboratory at the University of Maryland, monitored restored and degraded streams positioned in the headwater and the tidal boundary of a watershed in the Chesapeake Bay region. The project quantified nutrient reductions in restored streams where channel restoration practices had been implemented. The information in the project can be used to help develop a strategy for targeting stream restoration implementation in other watersheds in the same region, and to help improve predictions of nitrogen and TSS export in streams in Maryland.

Richardson, C.J., Flanagan, N.E., Ho, M., & Pahl, J.W. (2011). Integrated stream and wetland restoration: a watershed approach to improved water quality on the landscape. *Ecological Engineering,* 37, 25-39.

The authors, researchers at the Duke University Wetland Center, monitored water quality to assess the cumulative effect of restoring multiple portions of the Upper Sandy Creek and former adjacent wetlands. The researchers applied stream/riparian floodplain restoration, storm water reservoir/wetland complex, and a surface flow treatment wetland. The restoration resulted in functioning riparian hydrology that reduced downstream water pulses, nutrients, coliform bacteria, sediment, and stream erosion. They found that nitrate + nitrite loads were reduced by 64 percent, phosphorus loads were reduced by 28 percent, and sediment retention totaled almost 500 MT/year.

Rosgen, D.L. (2001). A practical method of computing streambank erosion rate. *Proceedings of the 7th Federal Interagency Sediment Conference.* Reno, Nevada.

The author, a researcher at Wildland Hydrology, Inc., uses a prediction model to quantitatively predict streambank erosion rates as a tool to apportion sediment contribution of streambank sediment source to the total load transported by a river. The model converts various stream parameter measurements and data to a normalization index for application for a range of stream types. The author also tested the indices against measured annual streambank erosion rates and presents various applications of the prediction method.

Selvakumar, A., O'Connor, T.P., & Struck, S.D. (2010). Role of stream restoration on improving benthic macroinvertebrates and in-stream water quality in an urban watershed: case study. *Journal of Environmental Engineering,* 136 (1), 127-139.

The authors, researchers at the USEPA and Tetra Tech, conducted pre and post restoration monitoring of a stream in Fairfax, Virginia to evaluate the effectiveness of stream bank and channel restoration as a way to improve in-stream water quality and biological habitat. After two years of monitoring, results indicated an improvement in biological quality for macroinvertebrate indices, however, all indices were below the impairment level, signifying poor water quality conditions. Their results also suggested that stream restoration alone had little effect on improving the conditions of in-stream water quality and biological habitat, although it lessened further degradation of stream banks.

Shields, C.A., Band, L.E., Law, N., Groffman, P.M., Kaushal, S.S., Savva, K., Fisher, G.T., & Belt, K.T. (2008). Streamflow distribution of non-point source nitrogen export from urban-rural catchments in the Chesapeake Bay watershed. *Water Resources Research,* 44, 1-13.

The authors, researchers at the University of North Carolina at Chapel Hill, the Center for Watershed Protection, the Institute of Ecosystem Studies, the University of Maryland, the USGS, and the USDA Forest Service, measured nitrogen concentration and discharge measurements to estimate loads. Their goal was to evaluate the impacts of urbanization on magnitude and export flow distribution of nitrogen in various urban and rural catchments. Forested, suburban, and agricultural catchments exported most of the total nitrogen and nitrate loads at lower flows, and conversely, urbanized sites exported total nitrogen and nitrate at higher and less frequent flows.

Sholtes, J.S., & Doyle, M.W. (2011). Effect of channel restoration on flood wave attenuation. *Journal of Hydraulic Engineering,* 137 (2), 196-208.

The authors, researchers at Brown and Caldwell, and the University of North Carolina at Chapel Hill, used a dynamic flood routing model to route floods in impaired and restored reach models, and examined the effectiveness of channel restoration on flood attenuation. Their analyses found that restoration most impacted floods of intermediate magnitude; however, their study shows that the current small scale of channel restoration will provide minimal enhancement to flood attenuation.

Sivirichi, G.M., Kaushal, S.S., Mayer, P.M., Welty, C., Belt, K.T., Newcomer, T.A., Newcomb, K.D., & Grese, M.M. (2010). Longitudinal variability in streamwater chemistry and carbon and nitrogen fluxes in restored and degraded urban stream networks. *Journal of Environmental Monitoring,* 13, 288-303.

The authors, researchers at the University of Maryland, the USEPA, and the USDA Forest Service, monitored surface and hyporheic water chemistry of restored and unrestored streams combined with a mass balance approach to investigate total dissolved nitrogen (TDN) and dissolved organic carbon (DOC) dynamics and in-stream retention and transformation processes. They found considerable reach-scale variability in biogeochemistry. TDN concentrations were typically higher than DOC in restored streams, and the opposite in unrestored streams. The mass balance in restored streams showed net uptake of TDN, and a net release of DOC, and the opposite pattern in unrestored streams.

Smith, S.M., & Prestegaard, K.L. (2005). Hydraulic performance of a morphology-based stream channel design. *Water Resources Research,* 41, 1-17.

The authors, researchers at the Maryland Department of Natural Resources and the University of Maryland, monitored a rehabilitation project in a reach of Deep Run in Maryland to assess commonly used approaches to channel design. They found that the constructed channel was morphologically and hydraulically different from the original channel, and was unsuitable. Their findings demonstrate the need for enhanced consideration of the relationship between channel stability and hydraulic conditions at multiple scales over a range of flow conditions in stream rehabilitation projects.

Sudduth, E.B., Hassett, B.A., Cada, P., & Bernhardt, E.S. (2011). Testing the Field of Dreams hypothesis: functional responses to urbanization and restoration in stream ecosystems. *Ecological Applications,* 21 (6), 1972-1988.

The authors, researchers at Duke University, compared ecosystem metabolism and nitrate uptake kinetics in restoration projects in urban watersheds, unrestored urban streams, and minimally disturbed forested watersheds. They found that stream metabolism did not differ between stream types in either summer or winter, and that nitrate uptake kinetics was not different between stream types in the winter. They observed restored streams had significantly higher rates of nitrate uptake during the summer, which they found could mostly be explained by stream temperature and canopy cover.

Swan, C.M., & Richardson, D.C. (2008). The role of native riparian tree species in decomposition of invasive tree of heaven (Ailanthus altissima) leaf litter in an urban stream. *Ecoscience,* 15 (1), 27-35.

The authors, researchers at the University of Maryland, analyzed decomposition rates of the invasive tree of heaven, and other native leaf species in an urban stream, complemented with laboratory methods. They found that the invasive leaf experienced rapid breakdown, but was slowed when mixed with native leaves. Their results suggest that the presence of native riparian tree species may mediate how invasive trees decompose in human-impacted streams.

Sweeney, B.W., Czapka, S.J., & Yerkes, T. (2002) Riparian forest restoration: increasing success by reducing plant competition and herbivory. *Restoration Ecology*, 10 (2), 392-400.

The authors, researchers at the Stroud Water Research Center, Ducks Unlimited, Inc., and the USDA Forest Service, assessed seedling survivorship and growth of several species of trees in response to various treatment methods over 4 years at two riparian sites near Chester River, Maryland. They found no significant difference in survivorship and growth between bare-root and containerized seedlings. The survivorship and growth was higher for sheltered versus unsheltered seedlings, and those protected from weeds using herbicide. Overall, the results suggest that crown closure over most small streams needing restoration can be achieve more rapidly by protecting seedlings with tree shelters and controlling competing vegetation with herbicides.

Tullos, D.D., Penrose, D.L, Jennings, G.D., & Cope, W.G. (2009). Analysis of functional traits in reconfigured channels: implications for the bioassessment and disturbance of river restoration. *Journal of the North American Benthological Society,* 28 (1), 80-92.

The authors, researchers at Oregon State University and North Carolina State University, compared physical habitat variables, taxonomic and functional-trait diversities, taxonomic composition, and functional-trait abundances in 24 pairs of control and restored sites in three land use type catchments. They observed that responses to restoration differ between agricultural/rural and urban catchments, and that channel reconfiguration disturbs food and habitat resources in stream ecosystems. Their results also suggest that taxa in restored habitats are environmentally selected for traits favored in disturbed environments.

Tullos, D.D., Penrose, D.L., & Jennings, G.D. (2006). Development and application of a bioindicator for benthic habitat enhancement in the North Carolina Piedmont. *Ecological Engineering,* 27, 228-241.

The authors, researchers at Oregon State University and North Carolina State University, describe the development, application, and evaluation of a method for assessing the effectiveness of stream restoration activities in enhancing four lotic habitats based on the presence of habitat specialists. They compared the presence of indicator genera in restored and unrestored sections to signify restoration success in re-establishing benthic habitats. Their results suggest that habitats in urban areas indicated the greatest enhancement, while the agricultural and rural sites did not show a clear trend of improvement or degradation in response to restoration activities.

U.S. EPA. (2010). *Chesapeake Bay Phase 5 Community Watershed Model. In preparation.* EPA 903S10002 – CBP/TRS-303-10, U.S. Environmental Protection Agency, Chesapeake Bay Program Office, Annapolis, MD.

The author, the USEPA, uses HSPF model code to simulate sediment transport as separate processes on the land and in the river. The document describes the three parts of sediment simulation in the Phase 5.3 Model to represent sediment sources, delivery, and transport in the watershed.

Violin, C.R., Cada, P., Sudduth, E.B., Hassett, B.A., Penrose, D.L., & Bernhardt, E.S. (2011). Effects of urbanization and urban stream restoration on the physical and biological structure of stream ecosystems. *Ecological Applications,* 21 (6), 1932-1949.

The authors, researchers at the University of North Carolina, Duke University, and North Carolina State University, compared the physical and biological structure of four urban degraded, four urban restored, and four forested streams in North Carolina to quantify the ability of reach-scale restoration to restore physical and biological structure. They observed that channel habitat complexity and watershed impervious cover were the best predictors of sensitive taxa richness and biotic index the reach and catchment scale, respectively. Macroinvertebrate communities in restored channels were compositionally similar to those in urban degraded channels. Their results suggest that reach-scale restoration is not successfully mitigating for the factors causing physical and biological degradation.

Waite, L. J., Goldschneider, F. K., & Witsberger, C. (1986). Nonfamily living and the erosion of traditional family orientations among young adults. American Sociological Review, 51 (4), 541-554.

The authors, researchers at the Rand Corporation and Brown University, use data from the National Longitudinal Surveys of Young Women and Young Men to test their hypothesis that nonfamily living by young adults alters their attitudes, values, plans, and expectations, moving them away from their belief in traditional sex roles. They find their hypothesis strongly

supported in young females, while the effects were fewer in studies of young males. Increasing the time away from parents before marrying increased individualism, self-sufficiency, and changes in attitudes about families. In contrast, an earlier study by Williams cited below shows no significant gender differences in sex role attitudes as a result of nonfamily living.

Walter, R.C., & Merritts, D.J. (2008). Natural streams and the legacy of water-powered mills. *Science,* 319, 299-304.

The authors, researchers at Franklin and Marshall College, mapped and dated deposits along mid-Atlantic streams that formed the basis for the widely accepted model for gravel-bedded streams. The collected data, along with historical maps and records suggest streams were historically small anabranching channels with extensive vegetated wetlands that accumulated little sediment, and stored organic carbon. They suggest that large numbers of milldams have buried the wetlands with fine sediment. Their findings show that most floodplains along mid-Atlantic streams are actually fill terraces, and historically incised channels are not natural archetypes for meandering streams.

Weller, D.E., Baker, M.E., & Jordan, T.E. (2011). Effects of riparian buffers on nitrate concentrations in watershed discharges: new models and management implications. *Ecological Applications,* 21 (5), 1679-1695.

The authors, researchers at the Smithsonian Environmental Research Center, combined geographic methods with improved statistical models to test the effects of buffers along cropland flow paths on connecting stream nitrate concentrations in the Chesapeake Bay watershed. They developed models that predict stream nitrate concentration from land cover and physiographic province, and compared models with and without buffer terms. They found that on average buffers in the Coastal Plain watersheds had higher nitrate removal potential than other regions. Model predictions for the study watersheds estimated nitrate removals based on existing cropland and buffer distributions, compared to expected nitrate concentrations if buffers were removed. In the Coastal Plain watersheds, current buffers reduce average nitrate concentrations by 0.73 mg N/L, or 50 percent of inputs from cropland, 0.40 mg N/L, or 11 percent in the Piedmont, and 0.08 mg N/L or 5 percent in the Appalachian Mountains. The model also suggests that restoration to close all buffer gaps could further reduce nitrate concentrations.

Appendix B Protocol 1 Supplemental Details

Protocol 1 – Credit for Prevented Sediment during Storm Flow - is presented in Section 5 and an example using the protocol is presented in Section 6. This Appendix provides supplemental details for the protocol and example.

Bank and Nonpoint Source Consequences of Sediment (BANCS) Method

The BANCS Method, developed by Rosgen (2001) quantitatively predicts streambank erosion rates based on two commonly used bank erodibility tools: the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS).

The literature review in Table B-1 includes information from studies that have utilized the BANCS Method across the country. While many studies have applied the method, there are few that have collected actual measurements of streambank erosion to validate the results of the BANCS Method and establish a level of accuracy. The literature indicates that the BANCS Method generally predicts streambank erosion within an order of magnitude. Regional characteristics where the method is applied are important to consider and adjustments to the BEHI and NBS may be necessary to provide an adequate prediction of streambank erosion. For example, Sass and Keane (2012) found that woody vegetation plays a vital role in bank stability in Northeastern Kansas. By adjusting the vegetation portion of the BEHI they were able to improve the correlation between BEHI and streambank erosion.

The Panel identified a series of potential limitations to the BANCS method, including:

- The method is based on the NCD stream restoration approach, which uses assumptions regarding bank full storm frequency that are not shared in other design approaches (e.g., LGS, RSC).
- Some studies have found that frost heaving may be a better predictor of stream bank erosion than NBS.
- Estimates of BEHI and NBS can vary significantly among practitioners.
- Extrapolation of BEHI and NBS data to unmeasured banks may not be justified.
- BEHI is not effective in predicting bank erodibility in situations where there are head cuts or storm drain outfalls.
- The method estimates sediment supply and not transport or delivery.

Despite these concerns, the Panel felt that the use of a method that allows the estimation of stream bank erosion from an empirical relationship between standard assessment tools (BEHI and NBS) and in-stream measurements justified its use for the purposes of crediting stream restoration. Furthermore, the literature indicates that further refinements to this method that can improve the adequacy. The Panel recommended several steps to improve the consistency and repeatability of field scoring of BEHI and NBS, as follows:

- The development of a standardized photo glossary to improve standardization in selecting BEHI and NBS scores.

- Continued support for the development of regional stream bank erosion curves for the BANCS Method using local stream bank erosion estimates throughout the watershed and a statistical analysis of their predicted results. Ideally, measured bank erosion rates within each subwatershed or County would be used to validate the BANCS Method specific to that location. Given that this data may not be readily available, additional methodology for adjusting the BEHI and NBS scores to accommodate local subwatershed characteristics may be useful. For example, adjustments to the BEHI to account for areas with predominantly sandy soils, agricultural channels, or legacy sediment.

- The BANCS method should only be performed by a qualified professional, as determined by each permitting authority.

- Extrapolation of BEHI and NBS to unmeasured banks should not be allowed unless photo documentation is used to provide the basis of extrapolation.

- If BEHI and NBS data are not available for *existing* stream restoration projects, the current CBP approved rate will apply.

Table B-1
Bank and Nonpoint Source Consequences of Sediment (BANCS) Method Literature Review

Source	Location	Application	Results/Recommendations
Shields River Watershed WQ Planning Framework & Sediment TMDLs (MDEQ, 2009a)	Shields River Watershed, south-central MT. Confined by mountains to the west and east and flows to the Yellowstone River	The BANCS Method was applied to HUC 6 watersheds at 16 reaches along Potter Creek and Shields River and in 13 additional tributary reaches within the TMDL Planning Area to estimate bank erosion for development of a sediment TMDL. The assessment method excluded 100% naturally eroding banks from the extrapolation and potential loads are assumed to be a combination of natural loads and anthropogenic loads associated with the use of reasonable land, soil, and water conservation practices.	Bank erosion was found to contribute 103,000 tons of sediment annually to water bodies within the Shields River TMDL Planning Area. The bank erosion method focuses on both sediment production and sediment delivery and also incorporates large flow events via the method used to identify bank area and retreat rates. Therefore, a significant portion of the bank erosion load is based on large flow events versus typical yearly loading. Uncertainty in loading estimates is addressed through an adaptive management approach where the TMDL and allocations can be revised as additional information is collected.
Estimating Bank	Wissahickon Creek	The BANCS Method was applied	The BANCS method predicted 4.2

Table B-1 Bank and Nonpoint Source Consequences of Sediment (BANCS) Method Literature Review			
Source	**Location**	**Application**	**Results/Recommendations**
Erosion in the Wissahickon Creek Watershed - Conference Presentation (Haniman, 2009)	Watershed near Philadelphia, PA	to 12 tributaries of the Wissahickon Watershed between Oct 2005 – Aug 2006. Bank pins were installed at 82 sites from 2006-2008.	million lbs of erosion/year. The bank pins estimated 2.3 million lbs of erosion/year (95% CI, +/- 2.5 million lbs/year). The BANCS Method predicts erosion within an order of magnitude. Bank erosion curves are difficult to develop. Understanding channel evolution is key.
Application of Rosgen's BANCS Model for NE Kansas and the Development of Predictive Streambank Erosion Curves (Sass and Keane, 2012)	The Black Vermillion Watershed, glaciated region of KS, northeast of the Flint Hills Ecoregion	3 subwatersheds were selected in the Vermillion Watershed with varied land uses and conservation practices, varied channel modification, and varied riparian corridor management. Each subwatershed included 3 study reaches. Streams in the watershed are low gradient (<0.01), typically entrenched, straightened through channelization, and have high vertical banks. The BANCS Method was conducted for the study reaches, in addition to streambank profiles (with erosion pins as a measurement check). The goal was to provide a tool that can accurately predict annual streambank erosion rates and sediment contributions from channel banks in Northeast Kansas.	The erosion prediction curves developed in this study displayed more variation than the original Yellowstone, Colorado, Piedmont, or Arkansas curves. Vegetation seems to play a vital role in maintaining bank stability in this region of NE KS. Erosion rates plotted against both BEHI score and NBS rating with each site's woody vegetation cover showed a clustering of sites with woody vegetation vs. sites without. Thus, the vegetation portion of the BEHI was modified and simplified, which resulted in consistent R^2 values of 0.84 and 0.88 and correct order of the BEHI adjective ratings. Bank materials may also play a vital role, as the soils are high in clay content that may act similar to bedrock when wetted.
Using BANCS Model to Prioritize Potential Stream Bank Erosion on Birch Creek, Shandaken, NY (Markowitz and Newton, 2011)	Birch Creek within Catskill State Park, NY	144 bank locations along 6.3 stream miles of Birch Creek (steep-gradient mountainous region) were assessed with the BANCS Method. Nine monumented stream bank cross-sections were installed and measured pre and post Hurricane Irene and Tropical Storm Lee flood events. The purpose of this investigation was to: 1) establish a baseline dataset to predict an annual stream bank erosion rate	The erosion processes accounted for in the BANCS model may differ in non-alluvial boundary conditions such as glacial till and/or glacio-lacustrine lake clays, and revetment as observed in the study area. These boundary conditions may influence the erosion rates in ways not predicted by the BANCS model. No apparent trend was observed when data from the 9 monumented cross-sections were plotted against

Table B-1
Bank and Nonpoint Source Consequences of Sediment (BANCS) Method Literature Review

Source	Location	Application	Results/Recommendations
		of Birch Creek using BANCS; 2) rank and prioritize site specific potential erosion; and 3) produce reach specific erosion ratings.	the BEHI and NBS ratings. The discrepancy appears to be because of the NBS method used. Only one out of the seven methods to assess NBS was applied to all geomorphic conditions along Birch Creek. When graphed separately it became apparent that the variables associated with the BEHI rating were a much more effective predictor of bank erosion than NBS.
Great Lakes Bank Erosion 516(e) Study – Conference Presentation (Creech, 2010)	Great Lakes Region	Used bank pins and bank profile measurements to develop regional curves for the BANCS method.	The presentation does not indicate how well the BANCS method predicted erosion found with the bank pins and profile measurements. It appears they are still doing measurements so may not have drawn conclusions yet.
Northwest Branch of the Anacostia River Bank Erosion Assessment – Conference Presentation (Crawford et al., 2009)	Anacostia River, Montgomery County, MD, 15.2 sq mile watershed that is 18% impervious. Streams have 700 – 1,000 ft forested floodplains.	Goal of the stream restoration project was to reconnect the channel with its floodplain. The BANCS method was used, along with bank profile surveys at 44 individual banks.	The calibrated NW-160 curve predicted 1,040 tons/year erosion, the Colorado curve predicted 1,298 tons/year, and the North Carolina curve predicted 910 tons/year. BANCS method seems to be a reasonable first estimate of bank erosion. Only utilized 2 NBS methods. Large woody debris is an important source of NBS. Trees on top of banks contribute to stability. BANCS method should not be used to calculate sediment delivered to downstream reaches as it does not take deposition into account.
Evaluating the BEHI on the Navajo Nation (Navajo Nation EPA, 2002)	Chuska Nation, Navajo Nation	Bank profiles and bank pins were surveyed and BEHI determined for 20 bank sites along 15 streams for the purpose of testing and calibrating the BANCS method.	Considerable error was found at most sites for the Yellowstone and Colorado regional curves. Although there is error, the model appears to operate qualitatively. All sites where erosion was predicted, experienced erosion. While considerable error exists at individual sites, values averaged or integrated across the project area were surprisingly accurate. The Yellowstone NP and Colorado USFS graphs underestimated erosion by

Table B-1
Bank and Nonpoint Source Consequences of Sediment (BANCS) Method Literature Review

Source	Location	Application	Results/Recommendations
			6% and 168% respectively. Given the great variability in bank composition, erosion mechanisms, and stream flow, it will take several additional years of data to determine the accurate predictive capability of the BEHI. Additional parameters may have to be developed to accurately characterize the Near Bank Stress in sand bed channels. Regardless of the quantitative merits of the BEHI, the field procedure provides a valuable qualitative assessment of stream bank stability for the technician, landowner, or manager.
Stony Run, Baltimore City, MD, Geomorphic Baseline Survey (Eng et al., 2007)	Stony Run, Baltimore City, MD	This study documents active channel adjustments, and will allow the City to compare pre- and post-restoration stream conditions to document the benefits of the restoration. 42 stream banks were assessed using the BANCS method. 9 existing monumented cross-sections were resurveyed, and 2 new cross-sections were surveyed.	A poor correlation was found between the measured erosion rates and the predicted erosion rate determined from the draft regional D.C. curve, which may have been due to changes in the BEHI and NBS procedures from Wildland Hydrology. Similar erosion rates were found at Moore's Run.
Impacts of land use on stream bank erosion in the NE Missouri Claypan region (Peacher, 2011)	Claypan region, NE Missouri	The goal of this project was to determine whether two ***modified*** Rosgen's Bank Erosion Hazard Index (BEHI) Procedures (SOP) used by the Michigan Department of Environmental Quality (MDEQ) would be applicable to streams in the Claypan region of NE Missouri. The procedures were tested using erosion pin data collected over three years in two sub-watersheds of the Salt River Basin. The first procedure uses a ratio of bank height to bankfull height and the 2nd procedure includes adjustment factors for	The erosion rates for the eighteen treatment reaches were weakly negatively correlated with 2008 and 2011 SOP BEHI total scores, respectively. Both 2008 and 2011 total scores covered a fairly narrow range, which suggests that one or more of the variables were scored very similarly across the treatment reaches. Another caveat to consider is that Rosgen's method incorporates near-bank velocity gradients and shear stress distributions, which are not incorporated into the survey methods of either MDEQ SOP

Table B-1
Bank and Nonpoint Source Consequences of Sediment (BANCS) Method Literature Review

Source	Location	Application	Results/Recommendations
		bank material and soil layer stratification.	examined here. No conclusions about the effectiveness of the BANCS method can be made.
Using a BEHI to Estimate Annual Sediment Loads from Streambank Erosion in the West Fork White River Watershed (Van Eps et al., 2004)	West Fork White River Watershed, NW Arkansas, 79,400 ac watershed	The Arkansas Department of Environmental Quality utilized a BEHI and data collected from surveys of streambank profile measurements to develop a graphical model to estimate streambank erosion rates and to estimate the annual sediment load due to accelerated streambank erosion. 24 permanent survey sites were established within 8 reaches for erosion measurement with bank pins from 2002-2003. 192 streambanks were assessed for BEHI and NBS (2002-2004). By relating the BEHI rating, the local NBSS, and the measured erosion rate at each permanent survey site, a graphical model to predict streambank erosion rates was developed.	The study did not provide accuracy estimates for how well the measured erosion rates correlated with the model they developed (regional curve). Bankfull discharge was met or exceeded on many instances during the study period. The survey data should represent erosion rates for years where bankfull flow is approached, equaled, or slightly exceeded. Lateral erosion rates predicted by the model were less than half the rates predicted by the Colorado model for a BEHI and NBSS combination rating of moderate and high. However, for other combinations of BEHI and NBSS, erosion rates predicted by the WFWR model were higher than those predicted by the other models by a factor ranging from 1.3 to 2.8 times.
Streambank Erosion Source Assessment, Upper Gallatin TMDL Planning Area (PBS&J, 2009)	West Fork Gallatin River watershed of the Upper Gallatin TMDL Planning Area, Gallatin and Madison counties, Montana	Sediment loads due to streambank erosion were estimated based on the BANCS Method at 30 monitoring sites (204 streambanks) covering 5.2 miles of stream between July and October of 2008. The reaches were located in low-gradient portions of the study streams where sediment deposition is likely to occur.	Average annual sediment load from the assessed streambanks was estimated at 397 tons/year. 30% of the erosion sediment load was attributed to accelerated streambank erosion caused by historic or current human activities, while approximately 70% was attributed to natural erosional processes and sources. The watershed streambank sediment load was estimated at 1,821 tons/year based on the stream segment sediment load extrapolated from the assessed streambanks. 33% of this load is due to anthropogenic disturbances. Through the implementation of BMPs, it is

Table B-1 Bank and Nonpoint Source Consequences of Sediment (BANCS) Method Literature Review			
Source	**Location**	**Application**	**Results/Recommendations**
			estimated that the total sediment load from anthropogenically accelerated streambank erosion can be reduced by 31% (186 tons/year). Direct measurements of streambank erosion were not made, so no conclusions can be drawn about the accuracy of the results from the BANCS Method.
A Practical Method of Computing Streambank Erosion Rate (Rosgen, 2001)	Lamar Basin in Yellowstone National Park, Montana and the Front Range of Colorado on the USDA Forest Service, Arapaho and /Roosevelt and Pike/San Isabel National Forests.	The BANCS Method is presented and is based on the idea that streambank erosion can be traced to two major factors: stream bank characteristics (BEHI) and hydraulic / gravitational forces (NBS). In 1987 and 1988, direct measurements of annual erosion were made using bank pins and profiles to test the BEHI/NBS relationship. 49 sites were selected in the Front Range Colorado and 40 sites were selected in the Lamar River Basin, MT.	The coefficients of determination, or r^2 values, for the correlation of BEHI to NBS were found to be 0.92 for Colorado and 0.84 for Yellowstone. A subsequent study in NC found that the data plots closely to the Colorado dataset, possibly due to a similar alluvial bank composition. Research in the Illinois River in OK showed that either velocity gradients or shear stress ratios predict better than cross-sectional area ratio for NBS. This study also found that flows 4 times bankfull stage generated the measured erosion rate, compared to Colorado and Yellowstone, that are associated with flows at or near bankfull. Research in the Weminuche River found that data collected at low flow can provide comparable results to the higher flows associated with Colorado and Yellowstone. Stratification by geologic and soil types should be accomplished to establish a family of curves for various geologic and hydro-physiographic provinces. Once a quantitative relationship is obtained, mapping changes in the BEHI and NBS ratings can be used to estimate consequence of change in locations beyond where the measured bank erosion data is obtained.
Priority Setting for Restoration	Whitewater River in the Driftless Area in	This project will develop a modified BANCS model and	This project is ongoing and is scheduled for completion December

Table B-1 Bank and Nonpoint Source Consequences of Sediment (BANCS) Method Literature Review			
Source	**Location**	**Application**	**Results/Recommendations**
in Sentinel Watersheds (Lenhart et al., Ongoing)	southeast Minnesota Elm Creek within Glacial Till Plains of the Blue Earth Basin in southern Minnesota Buffalo River within the Red River of the North Basin	calibrate it for different geomorphic regions of Minnesota using monitoring, modeling and historical data. BSTEM predicts erosion quantities from individual storm events, while CONCEPTS can model erosion, deposition and channel evolution over extended time periods. These analyses and assessments will be used to identify priority management zones for the intended purpose of reducing sediment and phosphorus loads in sentinel watersheds (areas that are representative of other watersheds in the same region).	2014.
Upper Jefferson River Tributary Sediment TMDLs and Framework Water Quality Improvement Plan (MDEQ, 2009b)	Impaired tributaries to the Upper Jefferson River - Big Pipestone, Little Pipestone, Cherry, Fish, Hells Canyon, and Whitetail creeks.	This document presents a TMDL and framework water quality improvement plan for six impaired tributaries to the Upper Jefferson River. Appendix G presents an assessment of sediment loading due to streambank erosion along stream segments listed as impaired due to sediment. The BANCS Method was done along 91 streambanks (3.89 miles of streambank).	A total sediment load of 742.4 tons/year was attributed to eroding streambanks within the monitoring sections. Erosion from the monitoring sites was extrapolated to the watershed scale. A total estimated sediment load of 44,576.3 tons/year was attributed to eroding streambanks. Direct measurements of streambank erosion were not made, so no conclusions can be drawn about the accuracy of the results from the BANCS Method.

TN and TP Concentration in Stream Bank Sediments

Table 5 in Section 5 shows the four Pennsylvania and Maryland studies in which the measured nutrient content of stream sediments consistently had higher nutrient content than upland soils, and were roughly comparable to the more enriched street solids and BMP sediments. Nutrient levels in stream sediments were variable. The Panel elected to use TN and TP concentrations documented by Merritts et al. (2010). Although this study focused on legacy sediments, it is also the most robust, with a sample size of 228. In addition these numbers align with recent findings from Baltimore County Department of Environmental Protection and Sustainability in comments to an earlier draft from Panelist Steve Stewart. Steve provided the data in Table B-2 collected from stream bed and bank samples from Powdermill Run and Scotts Level Branch in Baltimore County, MD.

Table B-2 Concentration of TN and TP in Stream Bed and Bank Samples from Powdermill Run and Scotts Level Branch in Baltimore County, MD			
	Mean	**Median**	**Sample size**
TP (mg/L)	1.78	1.61	77
TN (mg/L)	5.41	3.81	89

From Merritts et al. (2010):

"Our analyses of stream bank sediments produce average nitrogen (N) concentrations of 1300 ± 450 ppm for 1 S.D. (n = 228). These results equate to a loading of 2.6 ± 0.9 lbs N/ton of eroded sediment. The average concentration of sorbed phosphorus (P) in stream banks is 600 ± 195 ppm for 1 S.D. (n = 390). These results equate to a loading of 1.2 ± 0.3 lbs P/ton of eroded sediment.

The concentration of stream bank P generally is lower and more consistent from site to site than N, which might reflect: (1) different physical and chemical properties of P and N; (2) historical land use activities that might have caused historical nutrient enrichments within the watershed; and (3) the transport mechanisms that redistributed these "legacy nutrients" and stored them in valley bottoms."

Sediment Delivery Ratio

The scale at which the CBWM simulates sediment dynamics corresponds to basins that average about 60 to 100 square miles in area. The model does not explicitly simulate the contribution of channel erosion to enhanced sediment/nutrient loadings for smaller 1st, 2nd, and 3rd order streams not included as part of the CBWM reach network (i.e., between the edge-of-field and edge-of-stream), that is, scour and deposition with the urban stream channel network with these basins are not modeled.

Due to the scale issue, the CBWM indirectly estimates edge-of-stream sediment loads as a direct function of the impervious cover in the contributing watershed. The strong empirical relationships between impervious cover and sediment delivery for urban watersheds in the Chesapeake Bay were established from data reported by Langland and Cronin (2003), which included SWMM Model estimated sediment loads for different developed land use categories. A percent impervious was assigned to the land use categories to form a relationship between the degree of imperviousness and an associated sediment load (Section 2.5, Figure 1). These edge-of-stream loads were then converted to edge-of-field loads by comparing the average forest load estimates to

Natural Resource Inventory average CBWM forest loads at the edge-of-field. For additional documentation, refer to Section 9 of U.S. EPA (2010).

The CBWM operates on the assumption that all sediment loads are edge-of-field and that transport and associated losses in overland flow and in low-order streams decrement the sediment load to an edge-of-stream input. Riverine transport processes are then simulated by HSPF as a completely mixed reactor at each time step of an hour to obtain the delivered load. Sediment can be deposited in a reach, or additional sediment can be scoured from the bed, banks, or other sources of stored sediment throughout the watershed segment. Depending on the location of the river-basin segment in the watershed and the effect of reservoirs, as much as 70 to 85% of the edge-of-field sediment load is deposited before it reaches the main-stem of the Bay (U.S. EPA, 2010).

The sediment loss between the edge-of-field and the edge-of-stream is incorporated into the CBWM as a sediment delivery ratio. This ratio is multiplied by the predicted edge-of-field erosion rate to estimate the eroded sediments actually delivered to a specific reach (U.S. EPA, 2010). Sediment delivery ratios in the Phase 5.3 CBWM range from 0.1 to 0.25. In the protocol 1 example in Section 6, the median of this range, 0.175, was used. Localities will not be required to apply the sediment delivery ratio when submitting the load reduction attributed to stream restoration projects. The ratio is incorporated into the CBWM and is subject to change based on further refinements of the modeling tools.

Supplemental information for the Protocol 1 Example

The example for Protocol 1 uses actual stream bank data collected for Hickey Run in Washington, D.C, by the USFWS. The data consisted of five reaches that were subdivided into a total of 28 banks for BEHI and NBS assessments. The BEHI and NBS scores were taken for each bank and an estimated stream erosion rate was derived using the curve developed by the USFWS in Figure B-1. The bank height and length were used to convert the erosion rate from feet per year to tons per year using the equation described under Protocol 1 in Section 6.

Table B-3
Bank Erosion Potential for Hickey Run

Reach ID	Bank Length (ft)	Bank Height (ft)	Bank Area (ft^2)	BKF Height (ft)	BEHI	Near Bank Stress	Predicted Erosion Rate (ft/yr)	Predicted Erosion Sub-Total (ft^3/yr)	Predicted Erosion Sub-Total (tons/yr)	Predicted Reach Total Reach Erosion (tons/yr)	Predicted Erosion Rate (tons/ft/yr)
Reach 6											
Bank 1	376	10	3760	1.7	High	Low	0.4	1504.00	93.89		
Bank 2	260	4.5	1170	1.7	Low	Low	0.017	19.89	1.24		
Bank 3	144	6.5	936	1.7	High	Low	0.4	374.40	23.37		
Bank 4	578	15	8670	1.7	High	Low	0.4	3468.00	216.49		

Bank 5	329	8	2632	1.7	High	Low	0.4	1052.80	65.72		
Bank 6	381	12	4572	1.7	Very High	Low	0.4	1828.80	114.16	514.87	0.25
Reach 5											
Bank 7	160.5	10	1605	2.01	High	Low	0.4	642.00	40.08		
Bank 8	192	8.5	1632	2.01	Very High	Low	0.4	652.80	40.75		
Bank 9	122.4	2.3	281.5	1.4	Low	Low	0.017	4.79	0.30		
Bank 10	55	7	385	1.4	Very High	Low	0.4	154.00	9.61	90.74	0.17
Reach 4											
Bank 11	263.5	6.5	1713	2.59	Very High	Low	0.4	685.10	42.77		
Bank 12	73	6.5	474.5	2.34	Very High	Low	0.4	189.80	11.85		
Bank 13	195	7.5	1463	2.59	High	Low	0.4	585.00	36.52		
Bank 14	151	7.5	1133	2.2	High	Low	0.4	453.00	28.28		
Bank 15	352.5	7	2468	2.27	Very High	Low	0.4	987.00	61.61		
Bank 16	323	7	2261	2.71	High	Low	0.4	904.40	56.46		
Bank 17	395	7.5	2963	2.59	High	Low	0.4	1185.00	73.97		
Bank 18	59.4	7.5	445.5	2.2	High	Low	0.4	178.20	11.12		
Bank 19	231.5	6.5	1505	2.2	Very High	Low	0.4	601.90	37.57		
Bank 20	95.5	6.5	620.8	2.26	Low	Moderate	0.074	45.94	2.87	363.02	0.17
Reach 3											
Bank 21	132	6.5	858	1.88	Very High	Extreme	2.65	2273.70	141.94		
Bank 22	100	6.5	650	1.88	High	Low	0.4	260.00	16.23		
Bank 23	62.5	8	500	1.23	N/A	N/A	0	0.00	0.00		
Bank 24	50	20	1000	1.73	Very High	Extreme	2.65	2650.00	165.43		
Bank 25	175	3.5	612.5	1.48	Moderate	Low	0.11	67.38	4.21		
Bank 26	162.5	7.5	1219	1.48	Very High	Low	0.4	487.50	30.43	358.23	0.53
Reach 2	***Concrete Channel***										
Reach 1											
Bank 27	1170	7.5	8775	3.76	Low	Low	0.017	149.18	9.31		
Bank 28	1170	10.5	12285	4	Low	Low	0.017	208.85	13.04	22.35	0.01
									TOTAL	**1349.22**	**0.17**

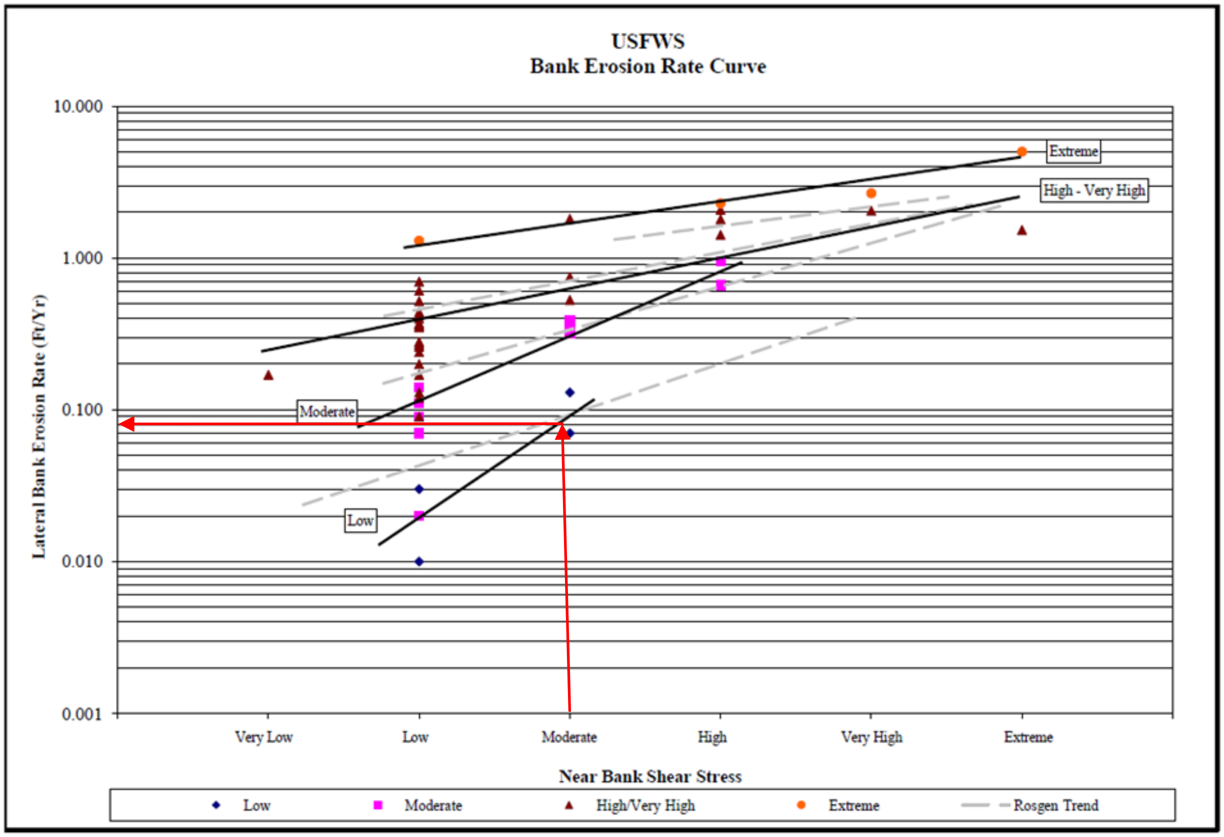

Figure B-1. Bank Erosion Rate Curve Developed by the USFWS

Stream bank erosion is predicted from the curve in Figure B-1 by first identifying the BEHI and NBS scores. For example, Bank 20 from Table B-3 had an NBS score of moderate and a BEHI score of low. By locating the moderate NBS score on the x axis of the Figure B-1 and following it straight up to the BEHI line for "low," the vertical axis shows a predicted erosion rate of 0.07 feet per year, as indicated by the red arrows on the figure.

To convert the erosion rate from feet per year to tons per year, a soil bulk density of 125 pounds/ft^3 was used. This estimate was obtained from a study by Van Eps et al. (2010) that sampled coarse and fine grain layers of stream banks in the West Fork White River watershed in Northwestern Arkansas to determine the in-situ bulk density and particle size distribution. The 125 pounds/ft^3 value used in the Protocol 1 example was calculated as the mean of the coarse and fine grain average bulk density measurements obtained by Van Eps et al. (2010). The bulk density from this study was used only as an example of typical values that might be found. The original bulk density data from the USFWS was not available. The protocol recommends that each project require its own bulk density analysis at several locations in the stream channel as bulk density can be highly variable.

From Van Eps et al. (2010):

"The average in-situ bulk density for fine grain material samples was 1.4 g/cm^3 (1.2 ton/yd^3). By weight, 8% of the particles in the fine material samples were greater than 2 mm in particle size. The average in-situ bulk density for coarse samples was 2.6 g/cm^3 (2.2 ton/yd^3). By weight, 80% of the particles in coarse samples were greater than 2 mm in particle size."

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Appendix C Protocol 2 and 3 Supplemental Details

Protocol 2 – Credit for Instream and Floodplain Nutrient Processing within the Hyporheic Zone during Base Flow and Protocol 3 – Credit for Floodplain Reconnection Volume during Storm Flow - are presented in Section 5 and examples using the protocols are presented in Section 6. This Appendix provides supplemental details for the protocols and examples.

Protocol 2 Method Documentation

Protocol 2 relies heavily on in-situ denitrification studies in restored streams within the Baltimore Metropolitan area (Kaushal et al., 2008; Striz and Mayer, 2008). After communication with two of the principal researchers of these studies, Dr. Sujay Kaushal and Dr. Paul Mayer, the Panel assumed that credit from denitrification can be conservatively estimated as a result of increased hyporheic exchange between the floodplain and the stream channel.

Striz and Mayer (2008) and Kaushal et al. (2008) conducted a study in Minebank Run, an urban stream in Baltimore County, MD to evaluate if particular stream restoration techniques improve ground water- surface water interaction (GSI) and if beneficial hydrologic exchanges between the stream and riparian/floodplain areas may be enhanced to improve water quality. Minebank Run is a second order stream located within the Piedmont physiographic region of Maryland with a drainage area of 3.24 square miles of mostly suburban land cover (25% impervious cover). Stream restoration techniques for the 1,800 foot channel followed the Natural Channel Design methodology and included filling the channel (and relocating in places) with sediment, cobbles, and boulders and constructing point bars, riffles, and meander features along the reach and creating step-pool sequences. The restoration also included a riparian corridor landscaping plan.

Their results show that a simple model splitting the stream into two compartments at the thalweg was sufficient to quantify the GSI flow (Figure C-1 below) and that significant differences in mean denitrification rates between restored and unrestored reaches and rates were higher at low-bank, hydrologically connected sites than at high-bank sites. Denitrification rates were 77.4 ± 12.6 μg N/kg/day of soil at restored sites and 34.8 ± 8.0 *mg N*/kg/day of soil at unrestored sites. The hydrologically connected, low-bank restored site consistently had significantly higher rates of denitrification than the other sites, with a mean in-situ denitrification of 132.4 *mg N*/kg/day of soil (2.65 x 10^{-4} pounds/ton/day of soil) (Table C-1). The Panel decided that this rate is representative of the denitrification that will occur as a result of Protocol 2.

To estimate the denitrification that would occur at a stream reach scale, Dr. Kaushal and Dr. Mayer, felt that a “hyporheic box” equal to the “restored” channel length multiplied times the width of the stream plus 5 feet on each sided and a depth of 5 feet below the stream channel would be very conservative and follow similar dimensions to the example in Figure C-1.

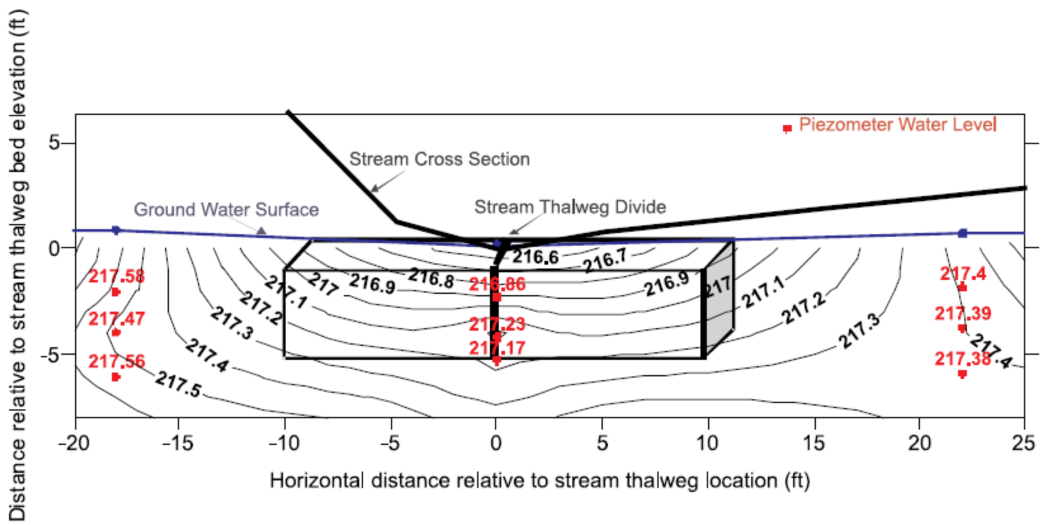

Figure C-1. Example vertical equipotential stream cross section with left bank and right bank compartments on either side of the stream thalweg divide from Striz and Mayer (2008).

Table C-1 Groundwater flow through a 1.5×1.5×1.5 m box adjacent to the restored reach of Minebank Run representing the riparian-zone-stream interface from Kaushal et al (2008)

Date	Q (m^3/d)	Denitrification rate (μg N·kg^{-1}·d^{-1})	Residence time (d)	Nitrate removal (μg N/m^3)
6 August	0.29	132.4	3.67	2806.5
2 September	0.55	132.4	1.91	1460.6
14 September	0.42	132.4	2.49	1904.1
21 September	0.42	132.4	2.49	1580.0
29 September	0.45	132.4	2.39	1516.6
5 October	0.41	132.4	2.60	1649.8
20 October	0.39	132.4	2.81	2202.7
17 November	0.37	132.4	2.98	2329.8

Note: The potential importance of estimates of mass removal of nitrate (in micrograms of N removed per cubic meter of groundwater flow) was investigated by coupling an average measurement of in situ denitrification rate during the study (in micrograms of N removed per kilogram of soil per day) on the south bank of transect 4 with a range of measurements of bank-to-stream groundwater flow during a three-month period in 2004 following denitrification measurements.

The mean bank height in the “restored connected” reach in Minebank Run was 77 cm compared to 114.7 cm in the “unconnected” reach. Reconnection was not necessarily defined as “floodplain” reconnection but connection between the stream channel and riparian zone to the groundwater interface or hyporheic zone. To define when “reconnection” would occur for qualifying for credit under this protocol, the Panel had proposed using a bank height ratio of 1.0 or less as this the definition. The bank height ratio is an indicator of floodplain connectivity and is a common measurement taken by steam restoration professionals using the natural channel design method. It is defined as the lowest bank height of the channel cross section divided by the maximum bank full depth.

In discussion with panel member Joe Berg, he pointed out that other design approaches do not use the bankfull storm, such as floodplain valley restoration or regenerative stream channel restoration. In those cases the reconnection criterion should be based on the return interval at which floodplain access occurs. If the bank height where reconnection to the floodplain occurs is equivalent to a storm event of 1.0 inches or less of rainfall then it can be assumed that hyporheic reconnection also occurs.

The Minebank Run study also demonstrated the importance of "carbon" availability in denitrification however the science determining how much is necessary is limited. Until more information becomes available, this protocol recommends that qualifying stream restoration projects include an extensive planting plan along the riparian corridor of the stream reach.

Protocol 3 Method Development and Spreadsheet Documentation

This credit is given when stream channels are reconnected to the floodplain resulting in hydromodification, where the floodplain is able to provide some level of pollution reduction volume to storms equal to or less than the one year storm event.

This method assumes that sediment and nutrient removal occurs only for that volume of annual flow that is captured within the floodplain area. The floodplain area is assumed to be a riparian wetland. The reduction credit for total nitrogen (20%), total phosphorus (30%) and total suspended solids 20% is taken from Jordan (2007) and reflects work that was approved through the Chesapeake Bay Program process.

These rates are lower than rates used in earlier versions of this draft that were based on stormwater treatment wetland efficiencies. Several panel members pointed out that riparian wetlands behave differently from stormwater treatment wetlands, which typically have much greater hydraulic detention times that allow for settling of particulates.

In developing this method, the following basic questions were asked:

A. How much runoff enters the floodplain?
B. How much of the floodplain (volume) can be considered wetlands?
C. How much of the runoff entering the floodplain receives effective treatment?
D. What is the nutrient removal efficiency of the floodplain wetlands?
E. What is the loading coming from the watershed?

The steps outlined in more detail below reflect the process for developing the curves used in the spreadsheet.

A. The spreadsheet determines how much of the annual runoff volume enters the floodplain for a range of storm classes. Rainfall records at National Airport were used in developing the graphs. Using a model like HEC-RAS, the designer would determine the flow depth over the floodplain. For instance, the depth might be 2 ft for a given discharge. The discharge is converted to a precipitation depth so that the rainfall frequency distributions at National Airport can be used. Figure C-2 below shows the runoff amounts entering a floodplain at two connection depths; one corresponding to a rainfall depth of 0.5 in. and the other 1.0 in.

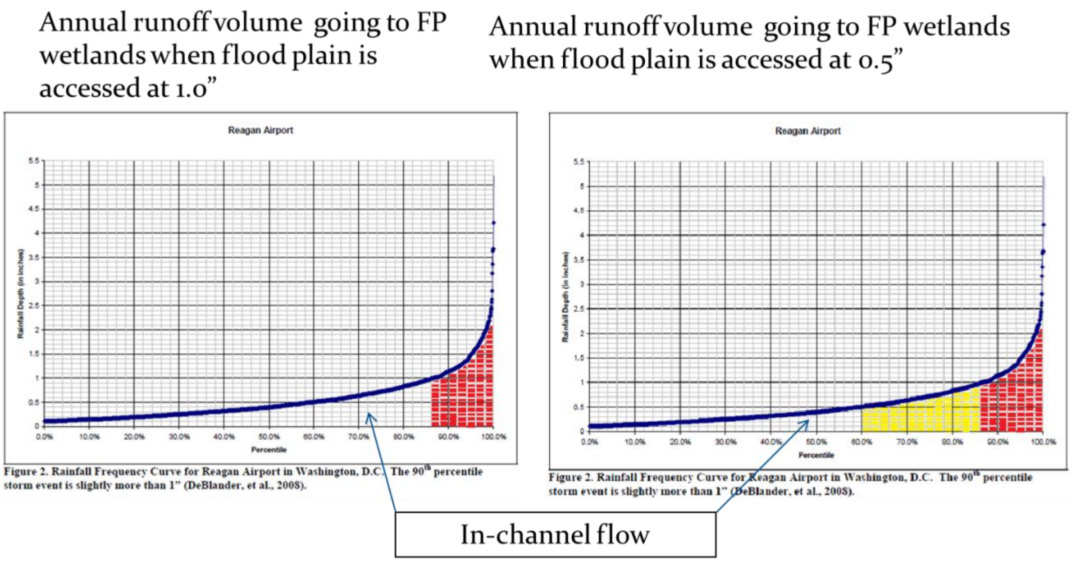

Figure C-2. Runoff amount entering the floodplain a connection depths corresponding to a rainfall depth of 0.5 in. and 1.0 in. based on National Airport rainfall data.

For instance, if reconnection occurred at 0.5 in. of rainfall (expressed as watershed inches) then only discharges resulting from storms exceeding this amount will enter the floodplain. All discharges (or rainfall depths) above this threshold discharge have the potential for being “treated” in the floodplain wetlands. Discharges below this amount are conveyed by the stream channel. The spreadsheet accounts for the frequency of events of 0.5 in. and greater that occur in a given year.

B. Figure C-3 shows the different floodplain storage volumes expressed in watershed inches (to make them dimensionless) along the x- axis. The average storage floodplain volume should be used for the full range of storms. The designer would typically develop floodplain storage volumes for different depths using site topography.

C. The curves on the graph in Figure C-3 represent the rainfall depths (rainfall is used instead of runoff to allow the use of the rainfall frequency distributions). In the example above, if floodplain reconnection occurs at a discharge equivalent to a rainfall depth of 0.5 in. (3rd curve) and there is floodplain storage of 0.25 in. (x-axis), then approximately 16% of the total annual runoff volume enters the floodplain (y-axis). The curves are developed for the discrete distribution of rainfall depths above those associated with the floodplain connection threshold (0.5, 0.75, 1.0…).

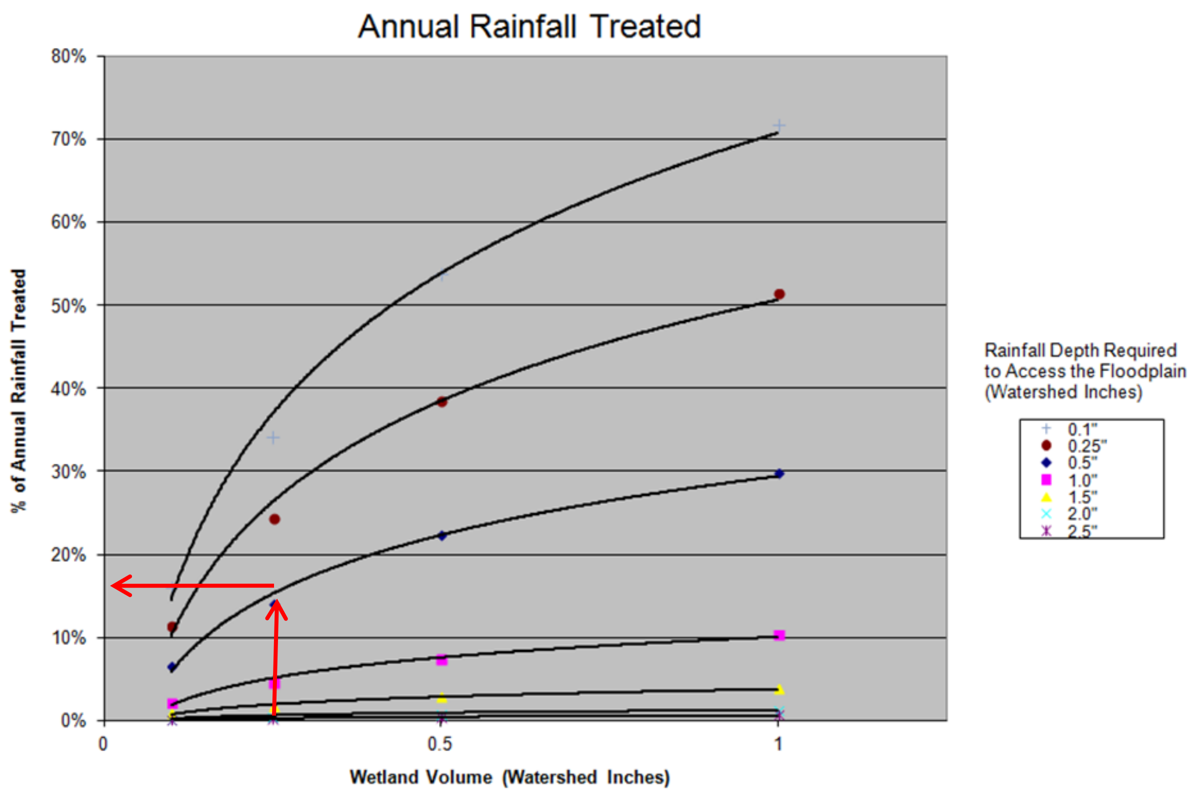

Figure C-3. Annual runoff volume treated as a function of floodplain storage volume for several rainfall thresholds that allow runoff to access the floodplain.

D. Once the fraction of annual runoff treated is determined, the wetland efficiencies from Jordan (2007) are used to convert these values to the percent TN, TP and TSS reduction. These graphs are shown on the Nitrogen, Phosphorus, and Sediment tabs (Figure C-4 for TN) of the spreadsheet. The y-axis is the percent along the y-axis from Figure C-3 multiplied by the reduction efficiencies from Jordan (2007). In the example above, if 16% of the annual rainfall runoff volume is being treated by the floodplain wetland, and the wetland efficiency for TN is 20% then the annual removal rate is determined by multiplying 16% by 20% or 3.2%.

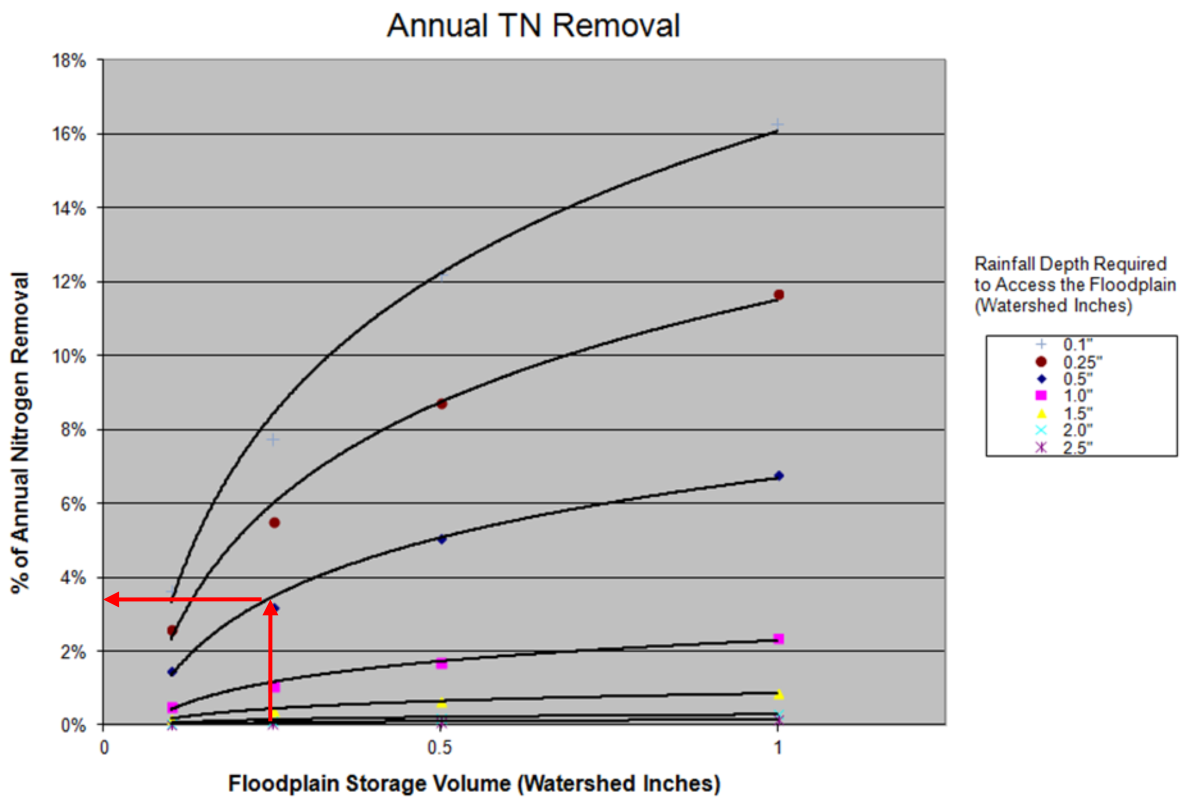

Figure C-4. Annual TN removal as a function of floodplain storage volume for several rainfall thresholds that allow runoff to access the floodplain.

E. The last step is to multiply the watershed loading from the CBWM (Table C-1) by the reduction efficiencies from Figure C-4. The Panel decided that the loading rates for impervious land provided an estimation of the load delivered during storm flow. These unit loads are readily available from CBP tools such as CAST, MAST and VAST. BMPs installed within the drainage area to the project will reduce the delivered loads by serving as a treatment train. The modeling team will discuss the possibility of incorporating treatment train effects into the CBWM and CAST[1]. If treatment train effects cannot be explicitly modeled in the CBWM and CAST, another option could be to first input all upland BMPs into CAST to determine the delivered loads to the stream restoration project and then use the resulting reduced loads for this step.

[1] A meeting is scheduled for 12/11/2012 between the modeling team and several Panel members to discuss the stream protocol and will include a discussion on modeling treatment train effects.

Table C-2. Edge of Stream Unit Loading Rates for Bay States Using CBWM v. 5.3.2						
BAY STATE	Total Nitrogen		Total Phosphorus		Suspended Sediment	
	Pounds/acre/year				Pounds/acre/year	
	IMPERV	PERV	IMPERV	PERV	IMPERV	PERV
DC	13.2	6.9	1.53	0.28	1165	221
DE	12.4	8.7	1.09	0.25	360	42
MD	15.3	10.8	1.69	0.43	1116	175
NY	12.3	12.2	2.12	0.77	2182	294
PA	27.5	21.6	2.05	0.61	1816	251
VA	13.9	10.2	2.21	0.60	1175	178
WV	21.4	16.2	2.62	0.66	1892	265
Source: Output provided by Chris Brosch, CBPO, 1/4/2012, "No Action" run (loading rates without BMPs), state-wide average loading rates, average of regulated and unregulated MS4 areas						

A detailed description of the spreadsheet analysis is described below.

1. Ordered the daily rainfall events for 30 years of data from least to greatest, and removed all events of 0.1" or less.
2. Summed the total rainfall volume.
3. Set floodplain depths (in watershed inches) of 0.5" – 2.5"
4. Set treatment volumes (in watershed inches) of 0.25" – 2.25"
5. Determine the value for each combination of floodplain depth and watershed inches by:
    a. Adding up all of the rainfall amounts between the floodplain depth and the floodplain depth + the treatment volume.
    b. Subtracting the floodplain depth from each event in the above sum.
    c. Adding the treatment depth for all rainfall amounts above the floodplain depth + the treatment volume.
    d. Dividing the total of a-c above by the total rainfall volume.
6. This value represents the percentage of the total rainfall treated by a given combination of floodplain depth and treatment volume.

The 88% in the stream restoration spreadsheet is based upon the assumption that the removal efficiency percentages we have for nitrogen and phosphorus are tied to the 1" storm. The 1" storm represents 88% of the rainfall volume in a given year (when all storms smaller than 1" and 1" per storm for all larger storms are summed). The removal efficiency percentages are therefore tied to the "benchmark" of 88%. To calculate the removal efficiency percentage for a given practice, the percent of annual rainfall volume captured is compared to 88%, and the resulting ratio is multiplied by the removal efficiency for the 1" storm. We did this for the previous version that used the wetland efficiencies based on stormwater wetlands. This is the approach that the Retrofit Panel used to adjust the retrofit efficiencies to account for removals at greater than the water quality treatment volume (1.0 inch).

An example:

A floodplain does not begin to fill until 0.5" of rainfall is reached, and has a 0.25" treatment volume. Given 374 storms between 0.5 and 0.75, 471 storms between 0.76 and 5.19 and 1125 storms in total:

a. Add up all of the rainfall amounts between 0.5" and 0.75" = 228.41"
b. Subtract 0.5" x 374 events = 187"; 228.41" – 187" = 41.41" *- 0.5 inch has to be subtracted because this amount never gets into the floodplain. The storage volume is only treating a fraction of these storms*
c. Add 0.25" for all rainfall amounts above 0.75" = 0.25" x 471 = 117.75": 41.41" + 117.75" = 159.16" - *treating the first .25 inches of storms greater than the bankfull*
d. Divide 159.16 by 1125.45" = 14.1% of total volume of runoff.

Alternative Method for Protocol 3 from Panel Member, Dan Medina

When detailed hydrologic and hydraulic data are available for the restored reach, the Protocol can be applied in a straightforward manner by following the steps below:

i. Calculate the volume of runoff that accesses the floodplain on an average annual basis
ii. Estimate the loads of nitrogen and phosphorus in that volume by multiplying the total pollutant load times the ratio of the floodplain runoff volume to the total runoff volume.
iii. Compute the nitrogen removal as 20% of the nitrogen load and the phosphorus removal as 30% of the phosphorus load.

Most of the complexity is in the first step but it is a straightforward calculationbecause hydrologic and hydraulic models are usually available as design tools. Below are two suggested procedures to accomplish this step, one for discrete storm modeling and another for continuous simulation.

Discrete storm modeling

1. Select a cross section representative of the restored reach
2. Using a hydraulic model such as HEC-RAS, compute the distribution of flows between the main channel and the "overbanks." This is a standard capability of all one-dimensional hydraulic models and results in plots similar to Figure C-5. The main channel is defined by suitable geomorphic indicators, for instance bankfull elevation, or geometric features when bankfull is not appropriate.

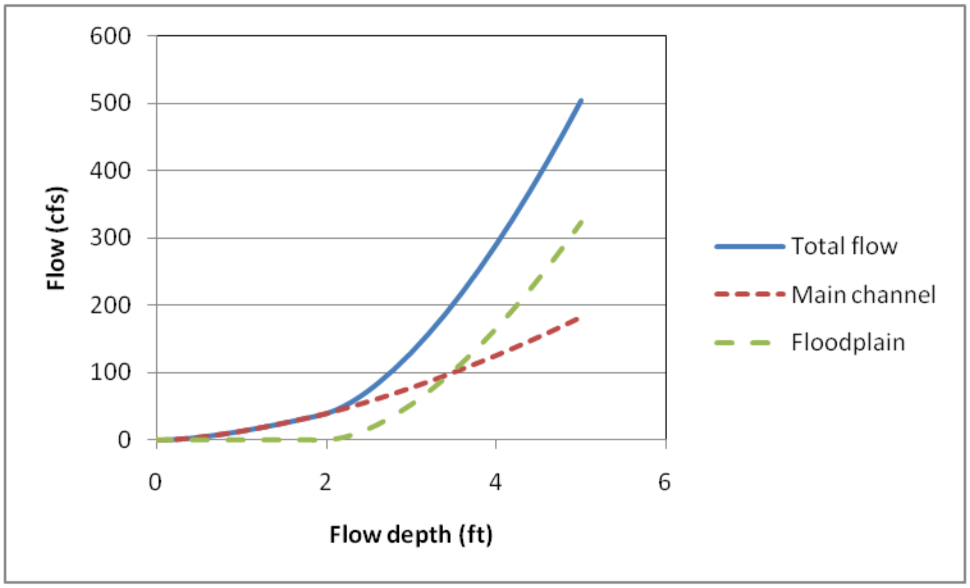

Figure C-5. Example flow distribution resulting from hydraulic modeling. This hypothetical example shows that the floodplain is accessed at a depth of two feet.

For application of Protocol 3, the tool needed is a plot of the floodplain flow as a function of the total flow as shown in Figure C-6. This relationship is a direct derivation from Figure C-5. For a given flow depth, the floodplain flow and total flow are plotted in Figure C-6.

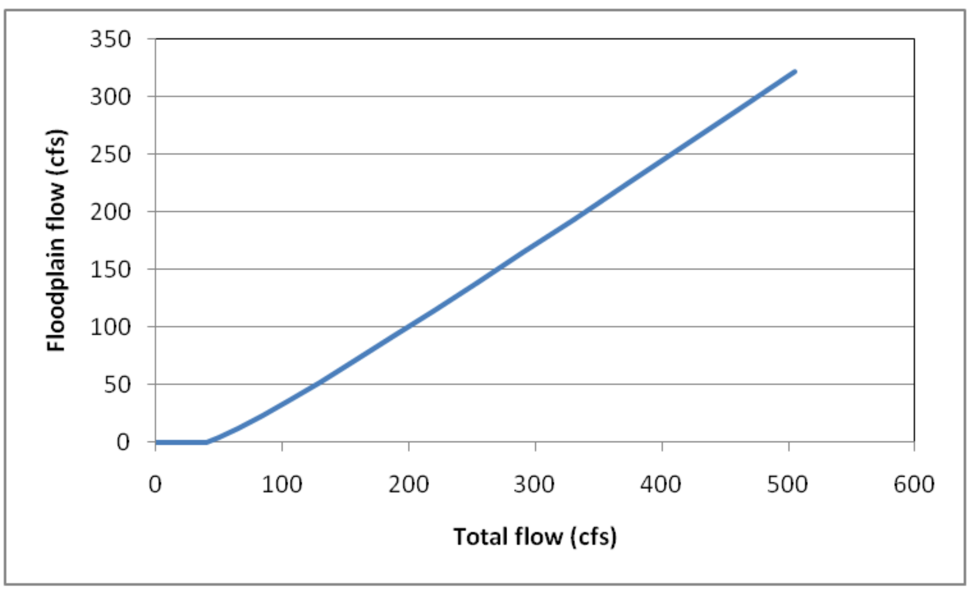

Figure C-6. Flow in the floodplain as a function of the total flow.

This relationship specifies how much of the discharge flows over the floodplain. For example, if the total flow is 200 cfs, about 100 cfs flow over the floodplain.

3. Run the hydrologic model for events of various return periods starting at the one-year flood.
4. Select the hydrograph corresponding to a given return period

5. Calculate the total runoff volume by computing the area under the hydrograph
6. Apply the relation in Figure C-6 to each ordinate of the total hydrograph and thus obtain the flow over the floodplains. If the flow depth over the floodplain is 1 ft or greater, then the flow for which credit is available is capped at the value corresponding to a depth of 1 ft over the floodplain. Figure C-7 shows a typical result.

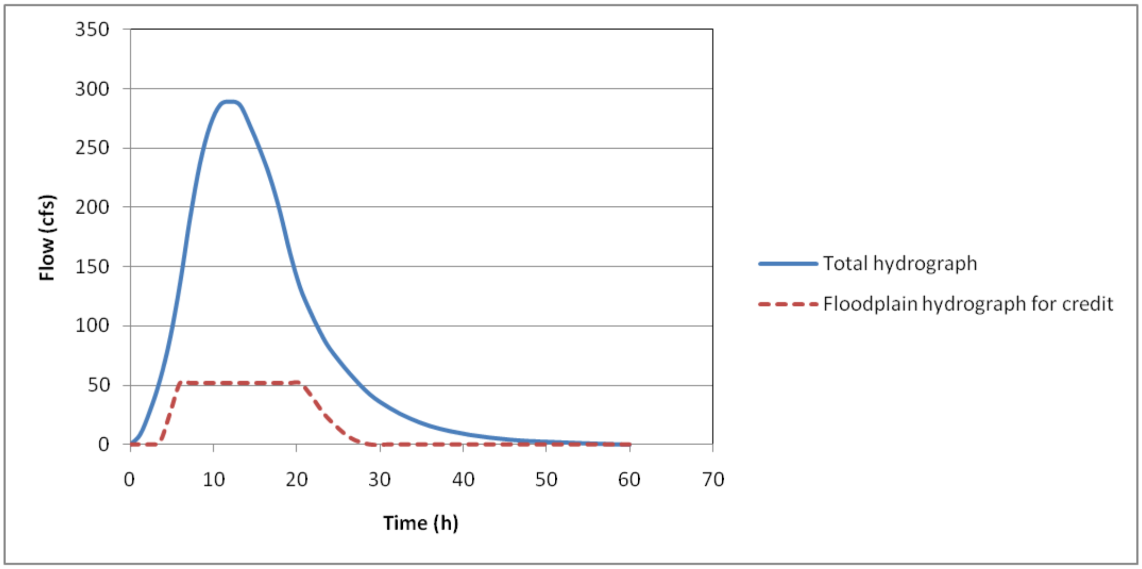

Figure C-7. Separation of the floodplain hydrograph. The horizontal portions at the beginning and end of the floodplain hydrograph indicate when the floodplain is not accessed. The horizontal portion in the middle indicates that the depth over the floodplain exceeds 1 ft and the maximum flow is set at the value corresponding to that depth.

7. Calculate the volume of runoff that flows through the floodplain by computing the area under the overbank hydrograph. For the example in Figure C-7, the total volume is about 383 ac-ft, whereas the floodplain volume is about 82 ac-ft.
8. Apply steps 4 through 7 for all other return periods
9. Construct a curve of the total runoff volumes versus their probabilities of exceedence, which are equal to the reciprocals of the return periods (e.g., the 5-year flood has a 1/5= 0.2 probability of being equaled or exceeded in any given year). The area under this curve is the average annual runoff volume
10. Construct another similar curve with the floodplain runoff volumes. The area under this curve is the average annual runoff volume that flows over the floodplains. The two curves are shown in Figure C-8.

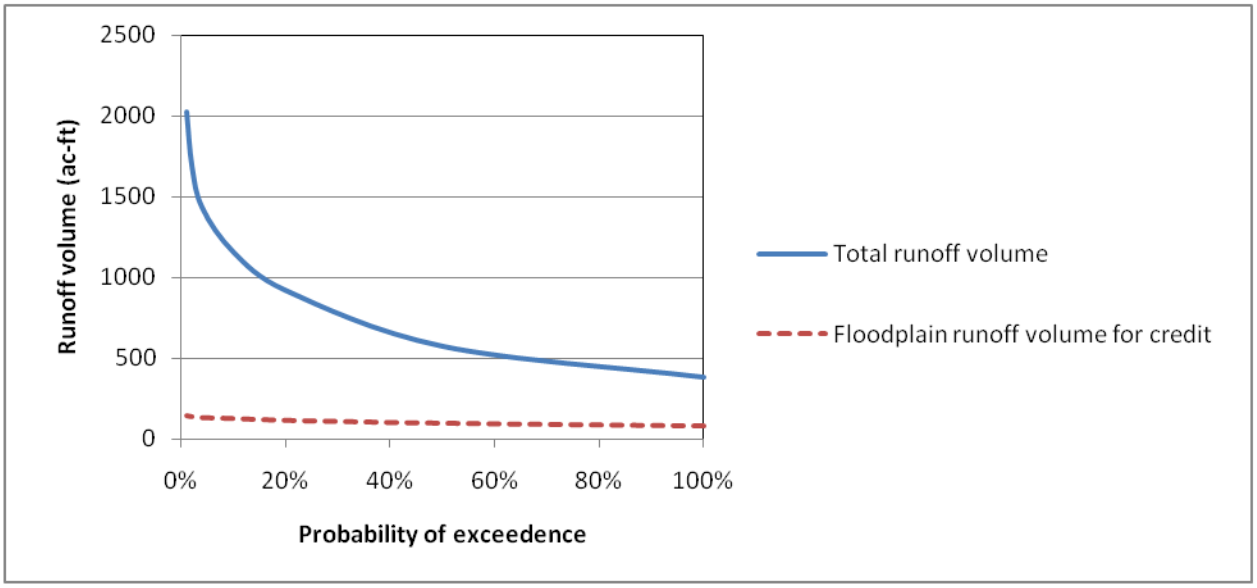

Figure C-8. Probability distribution of the total runoff volume and that flowing over the floodplain.

In this example, the average annual total runoff volume (the area under the solid curve) is 695 ac-ft, whereas the average annual runoff volume flowing over the floodplain is about 103 ac-ft.

11. The ratio of the floodplain runoff volume to the total volume is the fraction of the total runoff that comes in contact with the floodplain. For the example in Figure C-8, this ratio is 15%, which is the factor that will multiply the total pollutant loads coming from the entire watershed.

The loads from the watershed are determined from the CBWM. These loads must be modified to include the effect of upstream BMPs, which has two components: the load reduced by the treatment that takes place in the BMP, and the untreated load from the portions of large storms that bypass the BMP. Once the BMP effects are incorporated, the resulting loads are those that will come into contact with the floodplain. These loads have to be multiplied by the reduction efficiencies from Jordan (2007) for TN, TP and TSS.

Continuous Simulation

The discrete-storm approach is probably the most accessible to designers who are used to running hydrologic models for individual storms. However, increasingly more often, designers are beginning to apply continuous simulation to evaluate the performance of a design in response to a long-term period of rainfall, for example an average year, a wet year, of the full available rainfall record. Entering a continuous rainfall input dataset into the hydrologic model yields a continuous streamflow output dataset. In this case, the procedure outlined in Steps 1 and 2 is still carried out to derive the hydrograph separation relationship. This relationship is then applied to the continuous streamflow output from the hydrologic model in a manner analogous to Step 4. The result will be the continuous hydrograph over the floodplain.

The area under the hydrograph for the total flow is the total runoff volume in the period analyzed. Similarly, the area under the hydrograph for the floodplain is the runoff volume that accessed the floodplain during that period. The ratio of these two volumes is calculated and used as in Step 11.

References

Kaushal, S., Groffman, P., Mayer, P., Striz, E., and A. Gold. 2008. Effects of stream restoration in an urbanizing watershed. *Ecological Applications* 18(3): 789-804.

Striz, E., and P. Mayer. 2008. Assessment of near-stream ground water-surface water interaction (GSI) of a degraded stream before restoration. U.S. Environmental Protection Agency Office of Research and Development. EPA 600/R-07/058.

Appendix D Summary of Expert Panel Meeting Minutes

December 5, 2011
Meeting Minutes
Urban Stream Restoration Expert Panel

EXPERT BMP REVIEW PANEL Stream Restoration		
Panelist	**Affiliation**	**Present ?**
Deb Cappuccitti	MDE	Yes
Michael Bumbaco	Virginia Beach	Yes
Matt Myers	Fairfax County	Yes
Dan Medina	Atkins	Yes
Joe Berg	Biohabitats	Yes
Lisa Fraley McNeal	CWP	Yes
Steve Stewart	Baltimore County	No, Briefed on 11/23.
Dave Goerman	PA DEP	Yes
Natalie Hartman	WV DEP	Yes
Jeff Sweeney	EPA CBP	Yes
Josh Burch	DDOE	Yes
Robert Walter	Franklin and Marshall	Yes
Tom Schueler	CSN (FACILITATOR)	Yes

Summary of Action Items

The Panel directed Tom to (a) provide the sediment load/impervious cover model inherent in the Watershed Model and (b) Get Gary Shenk (EPA CBPO) to provide more detail on sediment and nutrient dynamics at its next meeting

Bob Walter agreed to provide Sujay with papers on sediment and phosphorus dynamics to add to the database. Tom requested that all panelists review the spreadsheet to determine if any important black and grey literature needs to be added to the spreadsheet, and if so, to provide the citation or pdf to Tom no later than December 20, 2011. Tom will forward these studies to Sujay and the panel as a whole. Sujay agreed to provide the entire non-Bay spreadsheet, and the panel agreed that each member would take on reviewing 10+ papers on the non-Bay list prior to our next meeting. Tom will work with the panel on doling out papers to the panel as a whole

The panel agreed to meet for a face to face meeting in Annapolis, tentatively scheduled for January 25th. The ¾ day meeting would have telephone connections for folks who cannot travel. The meeting would devote several hours on research presentations by Solange, McNeal (or Bill Stack), Kaushal, Walter, Stewart and others. Panelists who want to present their own data or nominate a colleague are asked to let Tom know by December 20.

1. **Call to Order and Panelist Introductions.** Tom Schueler called the meeting to order at 11 AM. Each of the panelists introduced themselves and explained their background in retrofit analysis and implementation in their jurisdiction. Tom briefly outlined the BMP review panel protocol by which the panel would conduct its business, and asked the panel whether they understood their role and had any questions about the protocol. Tom then outlined his role was to facilitate the panel, organize the research and methods, and document its progress, but not be involved in the decision-making process.

The Panel then discussed and approved the draft charge for the stream restoration panel. **The Panel** agreed that Regenerative Conveyance Systems (RCS) should be within the purview of the panels deliberation, with a majority of the panel concurring and no dissent. **Dave G** inquired whether it was within the charge to look at effect of stream restoration in less developed areas, and Tom indicated that the panel could make such recommendations if it felt they were justified. **Dan** inquired as to the nature of the panel's final product. Tom indicated that the under the BMP review protocol, it would be a technical memorandum that describes the definition, rates, qualifying conditions and reporting mechanisms with an appendix that summarizes the scientific data evaluated.

1. Background on the Original CBP Approved Nutrient Removal Rates

Tom presented some background on how the original stream restoration rates were derived eight years ago from Steve Stewart's single study. Tom noted that Steve's subsequent research on Spring Branch revealed higher rates, and that other studies in the Baltimore metro area reached similar conclusions.The key point being that the existing CBP-approved rate for urban stream restoration was no longer adequate and deserves updating. Tom also noted the many local governments in the Bay watershed were keenly interested in the panels' recommendations.

2. How Urban Sediment Delivery is Currently Modeled in the Chesapeake Bay Model

Jeff Sweeney (EPA CBPO) briefly described how urban stream sediment and nutrient dynamics are currently simulated in the current version of the Chesapeake Bay Watershed Model. **Joe** and **Bob** both noted the importance of stream channel erosion relative to upland sources of sediment and nutrient loads from urban lands. **Mark** noted that sediment loadings were scale dependent, with higher loadings discovered for zero and first order streams. The Panel directed Tom to (a) provide the sediment load/impervious cover model inherent in the Watershed Model and (b) Get Gary Shenk (EPA CBPO) to provide more detail on sediment and nutrient dynamics at its next meeting

3. University of Maryland Research Synthesis Project

Dr Kaushal concisely described their ongoing work to develop a research synthesis on nutrient and sediment dynamics associated with urban stream restoration projects. He provided an Excel spreadsheet (Attachment A) which contained a meta-data analysis on about 30 recent urban stream restoration research projects. **Dave** noted that the spreadsheet was dominated by nitrogen research, and **Bob Walter** agreed to provide **Sujay** with papers on sediment and phosphorus dynamics to add to the database. Tom requested that all panelists review the spreadsheet to determine if any important black and grey literature needs to be added to the spreadsheet, and if so, to provide the citation or pdf to Tom no later than December 20, 2011. Several panelists indicated they would like to see the non-Chesapeake Bay citations (which may number around 200 or so). **Sujay** agreed to provide the entire non-Bay spreadsheet, and the panel agreed that each member would take on reviewing 10+ papers on the non-Bay list prior to our next meeting. Tom will work with the panel on doling out papers to the panel as a whole.

4. Scoping of Technical Issues to Address

Several panel members indicated the importance of defining uncertainty in relation to the panel recommendation, and the need for practical definitions of various types of urban stream restoration practices, that reflect stream order, landscape position and restoration objectives. The panel agreed to take on these issues at its next meeting

January 25 2012
Urban Stream Restoration Expert Panel
RAPID STREAM RESTORATION DATA REVIEW WORKSHOP

Objective: Provide a forum for the panel to rapidly review urban stream restoration research in the Bay watershed as it relates to nutrient and sediment delivery

10:30 to 11:30	**Sediment/Nutrient Delivery in the Watershed Model**	G. Shenk, EPA
11:30 to 11:40:	**The Rapid Research Review Process**	Schueler/CSN
11:40 to 12:00:	**Spring Branch Data, Baltimore County**	S. Stewart/DEPRM
12:00 to 12:20:	**Baltimore City Stream Data**	B. Stack/ CWP
1:00 to 1:20	**Nitrogen Dynamics**	S. Kaushal/UMD
1:20 to 1:50	**Anne Arundel County Projects**	S. Filoso
1:50 to 2:20	**PA stream research**	Walter
2:20 to 2:40	**Virginia Sediment Work**	Medina/Atkins

NOTE: RESEARCH REVIEW POWERPOINT PRESENTATIONS AVAILABLE FROM CSN

Areas of Possible Concurrence

Stream restoration and the Bay Model

- The scale at which the CBWM simulates sediment dynamics are river segments that average about 60 to 100 square miles in size, and therefore do not explicitly simulate the contribution of channel erosion to enhanced sediment/nutrient loadings for most 1st, 2nd and 3rd order streams.

- The CBWM indirectly gets to this by assuming edge of stream sediment loads are a function of the impervious cover in the contributing watershed, using empirical relationships from Cronin and Langland (2004).

- The CBWM simulates only partial sediment delivery from the edge of stream to the main stem of the Bay (15 to 30%). This means there will be a strong scale effect in any estimate of urban stream restoration removal rates (i.e., a higher rate that occurs at the local project reach versus a lower rate for the sediment that actually reaches the Bay.

- Stream restoration as a BMP can be modeled in many different ways within the context of the current version of CBWM, a unit load reduction (BMP factor), a variable removal rate for edge of stream loads or a change in delivery factor. The rate can also be variable with respect to watershed space and flow (i.e., triggered over and above a flow threshold, differential rate between physiographic regions etc). The panel can utilize this versatility to best represent the suite of stream restoration practice(s).

- The CBWM does not currently account for differences in sediment grain size, and this could be an important refinement for the 2017 model revisions. The panel indicated a strong interest in working with the CBWM modeling team on recommendations for improving the simulation of urban stream and sediment, with an understanding that the model cannot necessarily incorporate a range of values

The Current EPA-Approved rate for urban stream restoration

- Several studies seemed to indicate that current estimate for stream restoration is extremely conservative (Stack/Stewart), and may need to be increased, at least for some classes of stream retrofit practices.

The prime objective of stream restoration is not pollutant reduction

- Stream restoration is a carefully designed intervention to improve the hydrologic, geomorphic, water quality and biological condition of degraded urban streams, and cannot and should not be implemented for the sole purpose of nutrient or sediment reduction. Urban stream restoration is generally only warranted in urban stream reaches that have been or are currently being degraded by upstream watershed development, or require protection of critical public infrastructure.

- A qualifying project must meet certain presumptive criteria to ensure that high-functioning portions of the urban stream corridor are not used for in-stream stormwater treatment (e.g., geomorphic evidence of active stream degradation, an IBI of fair or worse, hydrologic evidence of floodplain disconnection, etc.)

- In general, the effect of stream restoration on stream quality is amplified when BMPs are implemented upstream in the catchment to reduce runoff and stormwater pollutants and improve low flow hydrology. Projects that combine restoration with upland retrofits may merit an additional nutrient and/or sediment reduction.

Defining stream restoration practices

- The panel concluded that no single, universal removal rate could be applied to the wide range of stream restoration techniques that are being applied across the Bay, although it may be possible to develop rates or methods for certain categories of stream restoration.

- Several different classifications were proposed, including projects designed to provide:
    - natural channel design
    - floodplain reconnection
    - stream wetland complexes,
    - removal of legacy sediments (i.e., Big Spring)
    - woody debris
    - regenerative conveyance systems
    - stream bank stabilization

- The panel is encouraged to think through different possible classification schemes prior to the next meeting, depending on whether they are splitters or lumpers. Recommendations of the panel should have both a local and Bay-wide consideration.

- In doing so, they may need to identify a unique project design approach to define each stream restoration class (e.g., Rosgen analysis for Natural Channel Design) and determine if there are sufficient performance studies available for the class to estimate unique rates.

- Within each class, it may be important to define secondary characteristics that help define rates, such as landscape position, stream order and reach length.

A" Simple" Conceptual Model for an Improved Rate

The rate may be calculated as the combined effect of "prevented" channel enlargement and increased in-stream nutrient processing associated with the stream restoration project.

The Prevented Sediment Approach

- The primary effect of stream restoration is to prevent channel enlargement within the project reach, and retain bank and floodplain sediments (and attached nutrients) that would otherwise be lost from the reach.

- The mass of "prevented" sediment and nutrients by a stream restoration project depends on the monitoring design approach. Studies that rely on bank pins and soil nutrient content tend to provide robust estimates, over the long term for streams that are actively incising or enlarging. The effect can be masked in studies that measure changes in nutrient sediment concentration above/below the project reach (or in comparison to a reference reach) unless they capture enough of the storms that cause bank erosion.

- Several panelists provided predictive data on the effect of bank retreat and the nutrient content of bank and floodplain soils. The panel indicated a strong interest in comparing this and other data to see if it is possible to develop regionally specific rates.

- Bill Stack proposed a method using project specific design data to develop rates, based on bank height, bank erodibility hazard, and near bank stress. These parameters are currently measured/estimated in virtually every project that would qualify as stream restoration, and can be input into predictive equations by developed by Dave Rosgen, the U.S. Fish and Wildlife Service and others to derive expected bank retreat. Bill provided several other equations to convert into management units such as tons of sediments, and suggested that the Spring Branch efficiency method might be applied to the erosion rates. Several panel members were interested in looking at more detail for this option in further detail at the next meeting.

The In-stream Processing Approach:

- A great deal of recent science has looked at the impact of stream restoration on nutrient processing, with a strong emphasis on nitrogen. Based on a handful of studies in the piedmont and coastal plain, uptake and de-nitrification can reduce daily nitrate-N loads on the order of 0 to 40%. (Kaushal/Filoso). Other changes to other forms of nitrogen may occur, but probably do not change the mass exported through the reach. Several project factors may be associated with greater nitrogen reduction:

    - *Slow down stream flow (increased low flow retention time)*

    - *Add dissolved organic carbon(riparian reforestation and/or instream woody debris)*
    - *Reconnect stream to floodplain and/or wetlands*
    - *Upstream or lateral treatment by stormwater BMPs*

- It may be possible to identify specific design factors, individual practices, and riparian management factors associated with projects that might be expected to generally promote (or diminish) increased in-stream nutrient processing.

- There appears to be a connection between the length of a stream restoration project and the cumulative length of the upstream drainage network and/or the contributing drainage area to the project reach. Short restoration projects in large catchments do not have enough retention time or bank protection to allow nutrient and sediment removal mechanisms to operate, especially during storm events.

Impact of stream restoration is influenced by the dominant flow regime.

- Although it can be masked by the study design, there are clear differences in sediment removal rates during storm flow and base flow conditions, and the relative proportion of both flows determines annual reductions.

- During base flow conditions, the nutrient reductions appear related to the retention time within the project reach.

- During storm flow conditions, the impact depends on the size of the storm and/or discharge event. Just a few large storms each year account for most of the reductions in sediment (and sometimes for nutrients).

- The value of groundwater is mostly unknown and potentially underestimated. Hydro-modification is an important aspect of stream restoration.

Legacy sediments.

- Most stream restoration projects ultimately need to be interpreted in the context of the extent and depth of legacy sediments that exist within the study reach.

- The removal of legacy sediments and the subsequent recreation of wet meadow floodplain system shows significant promise to produce significant sediment and nutrient reduction benefits (although monitoring has just commenced on the first major demonstration project in Big Spring, and space constraints in some urban stream corridors may preclude full implementation this approach).

March 5, 2012
Meeting Minutes
Urban Stream Restoration Expert Panel

EXPERT BMP REVIEW PANEL Stream Restoration		
Panelist	**Affiliation**	**Present ?**
Deb Cappuccitti	MDE	Yes
Michael Bumbaco	Virginia Beach	Yes
Matt Myers	Fairfax County	Yes
Dan Medina	Atkins	Yes
Joe Berg	Biohabitats	No
Bill Stack	CWP	Yes
Lisa Fraley McNeal	CWP	Yes
Steve Stewart	Baltimore County	Yes
Dave Goerman	PA DEP	No
Natalie Hartman	WV DEP	Yes
Jeff Sweeney	EPA CBP	No
Josh Burch	DDOE	Yes
Robert Walter	Franklin and Marshall	Yes
Sujay Kaushal	University of Maryland	Yes
Solange Filoso	University of Maryland	Yes
Julie Winters	EPA CBP	Yes
Gary Shenk	EPA CBP	No
Bettina Sullivan	VA DEQ	No
Norm Goulet	NVRC	Yes
Russ Dudley	Tetra Tech (FACILITATOR)	Yes
Tom Schueler	CSN (FACILITATOR)	Yes

Summary of Action Items

The Panel met via conference call for a 2-hour discussion that covered possible areas of concurrence, summaries of the compiled research, and approaches to determining nutrient and sediment reduction rates.

The panel initially reviewed the Possible Areas of Concurrence document. Tom Schueler will be revising the document based on comments made by the panelists.

Research review by the panelists resulted in some action items. Lisa Fraley-McNeal will look into monitoring requirements and distribute to the rest of the panel for discussion as an agenda item at a future meeting. Bill Stack will work with Steve Stewart and Solange Filoso dig deeper into any possible gap between erosion rates and load reductions observed in the field.

Bill Stack presented on the BANCS method and agreed to write it up and distribute to the rest of the panel.

The next meeting (via conference call) of the Urban Stream Restoration panel is tentatively scheduled for April 10, 2012.

1. **Review of Possible Areas of Concurrence.** The meeting began by reviewing the Possible Areas of Concurrence document developed from the previous meeting. Specific

language in the document will be modified based on panelist's comments. Below are comments raised for specific sections of the document.

Stream Restoration and the Bay Model
The goal is to reduce sediment but sediment from upstream sources is still needed to replenish downstream tidal wetlands.

The Current EPA-Approved rate for urban stream restoration
It is unclear whether we have enough information to claim that the current estimate for stream restoration is extremely conservative, although studies have shown that the sediment export is higher. Consideration should be given to the effect of stream restoration over time. Stream restoration should be separated from upland restoration practices.

The In-Stream Processing Approach
A great deal of discussion was had regarding this approach, including a discussion on dealing with phosphorus versus nitrogen. Hydromodification should not be considered an important aspect of stream restoration.

A "Simple" Conceptual Model for an Improved Rate
In-stream nutrient processing should be expanded to include the riparian area, groundwater exchange, and other factors that influence the nutrient cycle. The mass of "prevented" sediment is dependent on the location within the watershed.

2. **Other Panel Presentations on their Research Reviews.** Four panelists prepared slides discussing their review of urban stream restoration research papers. These are summarized below.

Josh Burch
Josh noticed a range of restoration effectiveness and suggested there should be a tiered approach to stream restoration values. Perhaps restorations could receive a low/medium/high ranking depending on the effectiveness of the technique for nutrient and sediment removal. Steve Stewart suggested we should work with Chesapeake Bay modelers to incorporate temporal changes to the restoration projects.

Lisa Fraley-McNeal
During Lisa's review she discovered that there are no real seasonal differences and that a common theme to pollutant load reduction was slowing down the flow. She highlighted the importance of effective monitoring and Bob Walters asked what we can recommend to practitioners to get the monitoring data we need. Lisa is going to check on monitoring recommendations and report back.

Deb Cappuccitti
Deb questioned whether the studies really represented the condition of all stream restorations and pointed out one project that seemed to be deteriorating. She noted a potential gap between measured load reductions and the load reductions observed in the field. Bill Stack is going to work with Steve and Solange to delve deeper into this.

Solange Filoso
Solange determined that estimates for sediment load reductions shouldn't be the same for all stream orders. She also summarized that nitrogen concentration and riparian buffer connection is important to nutrient reductions. She commented that restoration effects can

be negative and that the age of the restoration should be considered, siting some restoration projects in NC as an example.

3. **Concepts for Classifying Stream Restoration Projects.** This discussion centered around the question, “Are project factors more important than restoration classes?” Dan Medina suggested that the focus should be on the specific project and should consider the condition of the stream. Bob Walters noted that it’s important to diagnose the problem correctly before restoration to determine the success or failure of the project. Bill Stack suggested that monitoring is required to ensure restoration is functioning over time.

   Steve Stewart noted that research studies are largely based on design classifications and that most studies do not partition out individual functionality, making the assessment of project factors difficult. There was general discussion on the use of design technique terms such as Regenerative Stormwater Conveyance and Natural Channel Design and whether those terms are proprietary and should be avoided.

4. **The Prevented Sediment Approach.** Bill Stack presented on the BANCS approach using methods developed by Dave Rosgen. He mentioned using data from Steve Stewart to determine an actual reduction rate. Bob Walter commented that there are more factors that can create bank erosion than just shear stress (i.e. freeze/thaw). Bill will write up the method and share with the panel. The goal is to see if an approach like this can be developed that would attempt to account for location differences within the watershed. It is also important to see how this compares to monitored data in order to improve the degree of certainty.

April 24th, 2012
Meeting Minutes
Urban Stream Restoration Expert Panel

EXPERT BMP REVIEW PANEL Stream Restoration		
Panelist	***Affiliation***	***Present ?***
Deb Cappuccitti	MDE	Yes
Michael Bumbaco	Virginia Beach	No
Matt Meyers	Fairfax County	Yes
Dan Medina	Atkins	No
Joe Berg	Biohabitats	Yes
Bill Stack	CWP	Yes
Lisa Fraley McNeal	CWP	Yes
Steve Stewart	Baltimore County	Yes
Dave Goerman	PA DEP	Yes
Natalie Hartman	WV DEP	No
Jeff Sweeney	EPA CBP	Yes
Josh Burch	DDOE	Yes
Robert Walter	Franklin and Marshall	No
Sujay Kaushal	University of Maryland	Yes
Solange Filoso	University of Maryland	**No**
Julie Winters	EPA CBP	Yes
Gary Shenk	EPA CBP	No
Bettina Sullivan	VA DEQ	Yes
Norm Goulet	NVRC	Yes
Tom Schueler, Cecilia Lane	CSN (facilitator)	Yes
Molly Harrington	CBPO	Yes
Non - Panelists: Russ Dudley - Tetra Tech,		

ACTION ITEMS

ALL Members to provide constructive comments in the next 2 weeks to create an improved draft of the framework document reviewed during the meeting.
ALL to work on Section 7 Future Research Needs
ALL to read through Lisa Fraley-McNeal's monitoring document and comment
Joe Berg to write up section describing RCS and the dry channel and wet channel options.
Joe Berg to write "Prevented channel erosion component (stormflow)" (Section 3, Protocol #1)
Josh Burch to write-up applicability to rural projects (Section 4)
Deb Cappuccitti to write-up "Dry Channel RCS effect" based on MDE guidance document (Section 3, Protocol #4)
Russ Dudley to write introduction to Section 3 on the Review of Available Science and can help with associated bullets.
Solange Filoso and **Sujay Kaushal** to write-up "Instream nutrient processing (denitrification) during baseflow" (Section 3, Protocol #2)
Bill Stack to consider Deb Cappuccitti's suggestion regarding estimating prevented sediment loss/ Protocol 1 and take the lead on writing up Accountability (Section 6)

Steve Stewart to write summary of uncertainties (Section 3)
Tom Schueler to work with Norm Goulet to check with Gary Shenk on how BMP degradation curves apply and draft "Definitions and Qualifying Conditions (Section 4)

MEETING MINUTES

Introduction/Announcements: Tom Schueler

- Objective of meeting to move from background review to recommendation determination.
- Seeking comments to the draft as a whole and pragmatic answers to questions/concerns raised

Review "Proposed Protocols for Defining Pollutant Reductions Achieved by Individual Stream Restoration Projects": The Panel spent time going through the draft document in the following structured manner:

- Overall reactions to document:
  - Josh Burch: Concern that protocol will add significantly to workload of stream restoration.
  - Deb Cappuccitti: Concerned that in the guidance for stream restoration credits, the process shows that local governments want specific numbers to plan for (eg budget figures prior to analysis).
  - Joe Berg: Protocol document shows great effort. Believes that Protocol 2, Option 2 has limited feasibility.
  - Matt Meyers: Intermediary between applied rate and monitoring data
    - Qualifying conditions to allow streams for mitigation to receive credit.
- Discussion of Protocol 1, Recommended Crediting Procedure for Prevented Sediment Loss during Storm Flow:
  - Method of converting bank erosion to pollutant loading: disadvantage of method is that it only accounts for nutrients associated with sediment.
  - Frost heaving may be contribute
  - Only takes into account sediment supplied, not delivered
  - A pictorial guide to support BEHI measurement procedures would be helpful
  - Spring Branch Study method: noted as the only study completed therefore justification for estimating the effect of BMPs, but not for using loading rate as constant across watershed.
    - **Deb Cappuccitti**: These numbers may be best because they reflect middle.
    - **Steve Stewart**: However, the numbers must work within the CBP model.
  - **Cappuccitti**: BANCs method results in numbers too high; Projects fail and lead to continued or increased loading; Spring Branch #'s in the middle and may be best to use
  - **Cappuccitti**: estimate erosion rate from a stable stream and subtract from nutrient loading estimates (Step 2) → **Bill Stack to consider this suggestion**

- Discussion of Protocol 2, In-stream Nutrient Processing:
  - Option 2 "Design Features" maybe superfluous: difficult to construct, hard to accomplish design required for reductions
  - **Julie Winters**: recommends keeping description to restoration, stay away from the term "credits".

DECISION: Option 1 in need of further work; however option 2 can be disregarded.

- Discussion of Protocol 3: Stream bank stabilization with flood plain reconnection and hydromodification
- This protocol is fairly rare
- Discussion of Protocol 4: Regenerative Stormwater Conveyance (RSC) Design
  - Protocol not developed
  - Joe Berg points to MDE 2011 guidance document for rates, notes there is a lack of monitoring data, use Bill Hunt data when panel reconvenes
  - Matt Meyers: Concern with outfalls/regenerative storm water conveyance systems

ACTION: Joe Berg to explore different types of channel designs to receive credits.

ACTION: Norm Goulet and **Tom Schueler** to check with Gary Shenk on how BMP degradation curves apply.

ACTION: Members to provide constructive comments in the next 2 weeks to create an improved draft.

- **Writing Assignments for Recommendations Memo:** The Panel was asked to take on specific sections for the final recommendations memo.
  - Section 3. **Russ Dudley** to write introduction and can help with associated bullets.
  - Section 3, Protocol #1. **Joe Berg** to write "Prevented channel erosion component (stormflow)"
  - Section 3, Protocol #2. **Solange Filoso** and **Sujay Kaushal** to write-up "Instream nutrient processing (denitrification) during baseflow"
  - Section 3, Protocol #4. **Deb Cappuccitti** to write-up "Dry Channel RCS effect" based on MDE guidance document
  - **Steve Stewart** to write summary of uncertainties (Section 3)
  - Section 4. **CSN** to draft "Definitions and Qualifying Conditions"
  - Section 4. **Josh Burch** to write-up applicability to rural projects
  - Section 6, Accountability. **Bill Stack** and **Lisa Fraley McNeal** to take the lead on
  - Section 7, Future Research Needs. **All** panelists to work on

- **Monitoring Research Summary:** Lisa Fraley McNeal discussed her review of existing stream restoration monitoring research.

ACTION: Come to a decision regarding a Monitoring Consortium.

  - MD Stream Restoration Association, recommend Bay-wide monitoring consortium to increase monitoring efforts in concentration and rigor

June 11th, 2012
Meeting Minutes
Urban Stream Restoration Expert Panel

EXPERT BMP REVIEW PANEL Stream Restoration		
Panelist	***Affiliation***	***Present ?***
Deb Cappuccitti	MDE	Yes
Bob Kerr	Kerr Environmental Services Corp.	Yes
Matt Meyers	Fairfax County	Yes
Dan Medina	Atkins	Yes
Joe Berg	Biohabitats	Yes
Lisa Fraley McNeal	CWP	No
Steve Stewart	Baltimore County	Yes
Dave Goerman	PA DEP	No
Natalie Hartman	WV DEP	No
Josh Burch	DDOE	Yes
Robert Walter	Franklin and Marshall	No
Sujay Kaushal	University of Maryland	Yes
Solange Filoso	University of Maryland	Yes
Julie Winters	EPA CBP	Yes
Bettina Sullivan	VA DEQ	No
Tom Schueler	CSN (facilitator)	Yes
Panel Support and Observers: Russ Dudley – Tetra Tech, Debra Hopkins – Fish and Wildlife Service, Patrick Shearer. Kerr, Bill Stack, CWP, Norm Goulet, Chair USWG, Molly Harrington, CRC, Cecilia Lane, CSN, Emma Gutzler, Fairfax		

ACTION ITEMS

Bill, Lisa, Sujay, Solange and Tom: Meet in July to discuss modifications to protocol 2 on instream nitrogen processing

Sullivan, Burch, Goerman, Hartman, Cappuccitti: Send Tom basic info on state stream restoration permitting process and key contacts to include in a Table in final report. Also, please check to see whether the writeup on Pre and Post Construction Monitoring Requirements is consistent with what is required for permits in your state

Matt Meyers to produce a table comparing sediment loading from degraded vs. natural urban streams, provide a summary of the USGS research on urban stream restoration, and develop a design example for a real Fairfax County project would be credited under protocols 1 and 4

Steve Stewart to write summary of uncertainties and develop a real world design example (e.g., Upper Mine Bank Run project) on how credits would work

CSN to draft a version of recommendations memo by July 15 and send out to panel for review

ALL: put together your key stream research and modeling recommendations and send to Tom by end of July

MEETING MINUTES

Introduction/Announcements: Tom Schueler

- Tom Schueler thanks everyone for attending this pivotal meeting
- Deb and Joe put together a write-up for RSC
- Goal of this meeting is to get pretty close to recommendations and identify any remaining issues that need to be dealt with
- RTV will need to be dealt with: if too stringent, will be disincentive; too loose, people will game the system; should mitigation projects qualify?
- Fish and Wildlife and EPA informal group meeting in mid-July to meet on RSC permitting issues – would help to have qualifying conditions prior to that meeting
- Debra Hopkins from FWS reps Habitat WQGIT observing the meeting today
- Russ Dudley put together a bibliography for an appendix – thank you
- **Action**: The Panel approved the meeting minutes from April

Proposed Outline Discussion: Tom Schueler went through the proposed outline for the technical memo (Appendix C) and asked for the Panel's feedback. The following comments were made:

- Section 7 should include panel recommendations on how to improve the CBWM which can be included in the planned 2017 model refinements
- Section 7: research recommendations. It was agreed the panel should emphasize priority research that improve the quality of the protocols that are recommended?
- Section 7 **Deb** suggested that the title for Section 7 should be changed to "future research and implementation needs" to ensure permitting consistency by regulatory agencies, local outreach and training and other efforts to implement the recommendations. The panel concurred.
- **Steve Stewart** mentioned developing a spreadsheet tool to assist people with calculations for each of the protocols. Tom Schueler agreed that it should be listed as a recommendation but noted that we do not have the budget to develop such a tool.
- **Meyers**: would help to have a table to compare degraded vs. natural urban stream compared to a natural stream would produce **Meyers will produce,** Include curve of imperviousness to sediment concentration
- **Action:** The Panel accepted the draft outline with aforementioned changes

Discussion on Prevented Sediment Protocol: Bill Stack and Steve Stewart led the Panel in a discussion on the prevented sediment protocol, with an initial focus on the difference in edge of field vs edge of stream sediment loads, as simulated by the CBWM and calculated by protocol 1 (see stewart memo and stack response. After a lengthy discussion, the panel recommended that we address this issue in our modeling recommendations and get some additional feedback from CBP modeling team to ensure the load reductions under the protocol are consistent with CBWM. Tom and Bill to work Gary Shenk of CBP to resolve this issue.

There was some discussion about whether the BANCS method is applied to legacy sediment removal projects, and whether these rural projects had a higher streambank nutrient content (as suggested by the sediment nutrient table prepared by CSN). The Panel consensus was that the BANCS method as well as Protocol 3 would both probably apply to legacy sediment projects, and that Tom should consult with Walters to get his take on a 2-tier approach for urban and rural(ag) stream bank nutrient content approach. The panel agreed that the urban numbers appear reasonable and are fine as a default, but it would always be preferable to obtain nutrient content numbers directly from the project data.

Action: The Panel directed CSN to do a more detailed writeup on Protocol 2 reflecting their consensus

Dry and Wet Channel RSC Definitions and Proposed Rates: Joe Berg and Deb Cappuccitti led the Panel in this discussion. They noted that the report should reference Anne Arundel County's approved practice specification (Reg. Step Pool Conveyance System) and the 2011 MDE's NPDES MS4 permit document. They proposed a dry and wet definition, based on where the practice is implemented in the stream network, the appropriate environmental conditions, and the size of the drainage area. The dry channel RSC would be treated as a stormwater BMP with a fixed removal rate , whereas the wet channel would be calculated using the appropriate protocol(s) for which it qualifies.

Action: The panel concurred with this approach, but wanted to see more detail in the definition and writeups in the next draft

Refinement of Protocols for In-stream N processing Effect: Sujay Kaushal, Solange Filoso and Bill Stack led the Panel in a discussion of in-stream Nitrogen processing. There was considerable panel discussion on the proposed protocols, and although progress was made, no firm consensus was reached.

Action: Sujay, Solange, Lisa, Bill and Tom agreed to meet in July to further refine the protocol, and present a recommendation to the panel.

Some key themes of the discussion on instream processing (no reconnection):

- Need to come up with an operable definition of the floodplain, and the hydrologic volume that occurs during re-connection (for both baseflow and stormflow)
- If there is little or no floodplain reconnection, than the amount of instream nitrogen processing will be limited?
- There was some support for Protocol 2, Option 1 (Forestry workgroup method that looks at the effect of riparian forests and wetlands in the stream corridor), with some modifications.
- Need an operable definition of the stream baseflow component of N load (i.e, the only effective treatment would be during baseflow conditions
- What % of annual load is in baseflow? Stack estimates 20%. Steve Stewart, Bob Shedlock (USGS) say there's even more variability than that
- Tom proposed an alternative which was to use the actual CBWM pervious land loading rate (discounted by 40% to eliminate surface runoff from pervious lands). Some support for this approach
- Sujay: denitrification can happen in stream: algae, microbes – dependent on amount of light., C/N ratio, O2 levels in stream
    - Combining the options may be a good approach: b/c accounts for variability, allows for flexibility based on specific project
    - Quantitative assessment for contribution of groundwater and stormwater in the crediting process, understanding the site in advance, during baseflow to do a simple water balance preconstruction = b/c groundwater contribution is key to the crediting process

- Some key themes of the discussion on instream processing (w/ reconnection):

- in-stream nutrient processing cuts off during high in-channel flows
- Stewart: most of denitrification taking place in wetland/forest corridors;
- More quantitative assessment of floodplain connectivity (Method 3) = can be done by bank height
- **Stack**: bank height is included in Method 3, but may need to be spelled out a bit more
- Not sure that Method 3 should be predicated on the 1" storm as the event to define the storm runoff volume that is captured in the floodplain. Perhaps a set of curves could be developed to express the new connection storm volume as a function of rainfall depth or runoff depth volume?
- **Kaushal:** May want take a similar approach to baseflow reconnection but base on field measurement of baseflow in the study reach.
- **Berg/Stewart**: challenge with monitoring small streams, accuracy is reduced. Also, daily cycle with baseflow, seasonal variation in baseflow, long-term variation, antecedent rainfall events will affect basefloew conditions
- **Sujay:** could average longitudinal, and daily variation; even if underestimate the baseflow at the time, N is also variable conservative, general approach
- **Solange**: important to determine what the dominant form of export of nutrients in urban streams prior to choosing protocol (possibly via LULC and topography) i.e. is stormflow the dominant form of export → Protocol 3 etc. The large storms define the Nutrient export of streams
- Stewart: need 2 methods: local gov'ts need multiple options: an easy one for less credit, more advanced restoration technique that would allow for more credit keep local governments' resources (and knowledge base) under consideration.
- **Stewart/Meyers:** to write up example projects on Upper Mine Bank Run and unspecified Fairfax County project: describe the project, how it would be credited

Discussion on Other Key Elements of Recommendations: The Panel discussed the proposed write-up on the key non-nutrient recommendations that was supplied in advance of the meeting

Action: The Panel directed CSN to proceed with a more detailed version to be included in the draft recommendations memo, and contributed the following insights

- Section 1: Environmental Considerations and Permitting
    - Medina: IBI only refers to biological health…not necessarily water quality
    - Solange: Meyers: reconnecting/maintaining the riparian corridor necessary, Need to add the following:
        - *A qualifying project maintains or enhances the riparian corridor, compensating for any project related losses*
- Section 2: Qualifying Conditions for Stream Restoration Projects
    - Should the minimum be 100'? Seems reasonable
        - Berg: Spot Treatments: Typical projects are several miles long but only stabilize sections of the stream: Need to differentiate between
        - "study reach" and "work areas" with prevented sediment credit for eroded areas defined by BANCS method and should be clearly articulated in a design example
    - Berg doesn't like qualifying conditions "state-approved design methods" b/c state has not pioneered these designs, Tom suggested adding **a table that indicates the state and federal permitting authorities that need to be consulted regarding restoration projects**
    - Existing Stream Restoration Projects

        - Old projects without BEHI curves will default to interim rate
- Section 4: Stream Mitigation and Nutrient Trading Issues
    - When a 404 permit it is issued there will be an impact
    - Nutrient trading: stream restoration is an option but more stringent requirements
    - Specific bullet for offset (different from trading)
- Section 5: Applicability of Protocols to Non-Urban Stream Projects
    - Berg: define rural vs. urban
    - Not prepared to make recommendations for ag streams for various reasons but the urban rate may apply however will be conservative
- Section 6: Provisions for Local Tracking, Reporting and Verification
    - Duration
        - Stewart: proposed 5 year verification timeframe should be linked to probability of failure i.e. stream restoration projects more likely to fail within the first 2 years; after that should go to 10 years
        - Bob Kerr: do we need a specific timeframe or just tie to TMDL updates?
- Section 7: Pre and Post Construction Monitoring Requirements
    - **Each of the state reps look at the general description and decide if it's good enough**

September 25th, 2012
Meeting Minutes
Urban Stream Restoration Expert Panel

EXPERT BMP REVIEW PANEL Stream Restoration		
Panelist	***Affiliation***	***Present ?***
Deb Cappuccitti	MDE	Yes
Bob Kerr	Kerr Environmental Services Corp.	No
Matt Meyers	Fairfax County	Yes
Dan Medina	Atkins	Yes
Joe Berg	Biohabitats	Yes
Lisa Fraley McNeal	CWP	Yes
Steve Stewart	Baltimore County	Yes
Dave Goerman	PA DEP	No
Natalie Hartman	WV DEP	Yes
Josh Burch	DDOE	Yes
Robert Walter	Franklin and Marshall	No
Sujay Kaushal	University of Maryland	No
Solange Filoso	University of Maryland	Yes
Julie Winters	EPA CBP	No
Bettina Sullivan	VA DEQ	Yes
Tom Schueler	CSN (facilitator)	Yes
Panel Support and Observers: Russ Dudley – Tetra Tech, Rich Starr – Fish and Wildlife Service, Lucinda Power, EPA CBPO, Jeff Sweeney, EPA CBPO, Matt Johnston, EPA CBPO, Bill Stack, CWP, Norm Goulet, Chair USWG, Jeremy Hanson, CRC, Cecilia Lane, CSN		

MEETING MINUTES

Review/Approval of June Panel Meeting Minutes and July Subgroup Minutes: Tom Schueler (CSN) began the meeting by thanking all of the panelists for their hard work and their feedback on the technical report.

ACTION: The Panel approved the meeting minutes from June Panel meeting and the July subgroup meeting. The Panel decided to accept comments on the technical report until October 12, 2012.

Tom noted that a number of panelists have contacted him regarding the framework of the permitting recommendations. **Tom** noted that Nick DiPasquale (Director, CBP) has formed a permitting workgroup for a regional permitting approach to address many of techniques being discussed in panel. The workgroup is entitled: *Stormwater Management, Stream Restoration and Wetland Restoration Workgroup*. **Joe Berg** (Biohabitats) noted that he doesn't think that the Panel is the appropriate place for recommending regulatory guidance rather it is the charge of the panel to focus on water quality TMDL issues. **Deb Cappuccitti** (MDE) noted that as an employee of a regulatory agency it would not be possible to divorce herself completely from any potential conflicts within her administration. **Tom** pointed out that this is not an uncommon situation for panelists, so panel members are encouraged to propose language that allows flexibility for state programs. **Solange Filoso** (UMD) noted that it might be appropriate to recommend an independent review of the final technical document.

Presentation on Stream Functional Assessment, *Rich Starr, US FWS*
Rich Starr discussed how the stream functions pyramid framework may be a useful tool to ensure that stream restoration projects provide more functional uplift than just increased nutrient removal. His main conclusions can be found in his presentation. The following are some of the discussion highlights:

- Difficult to make changes in level 1; practitioners have most influence in level 2 variables; Site selection is very critical if you want to achieve a healthy stream
- Goal to think about all parameters occur in stream corridor, how they are interrelated and if they are/not functioning
- Where you enter in the pyramid depends on one's goals and objectives
- Can change the performance standard to apply to a specific set of goals
- **Joe Berg** noted that floodplain connectivity and access to organic rich sediments and a good storage volume in the stream channel are all necessary for good stream restoration projects. **Rich** noted that while his examples were focused on NCD projects, other kinds of stream restoration projects could be assessed, as long as the appropriate performance indicators were selected.

Updates on the Floodplain Reconnection Protocol, *Bill Stack, CWP*
Bill briefly reviewed the changes to the floodplain reconnection protocols that were discussed at the July subgroup meeting, indicated how the curves were created for Protocol 3, and laid out the remaining technical decisions that the Panel needs to make on this topic. His main conclusions can be found in his presentation. The following are some of the discussion highlights:

- Basic premise is that denitrification occurs in stream channels and floodplain reconnection. The methods make the assumption that denitrification occurs b/c stream channel/floodplain behaves much like a wetland. Can use wetland studies to apply denitrification credit by estimating how stream channel behaves like a wetland.
- Baseflow (Protocol 2):
  - Surface area is critical to estimate denitrification credit
  - If we meet 1% threshold of the wetland to drainage area surface ratio can meet N removal rates in Table 6 (Step 2)
  - Unit loading rates for pervious areas only and adjusted for interflow
- Floodplain reconnection (Protocol 3):
  - Estimate how much storage volume available in floodplain area
  - Berg: if have floodplain that is connected at 1" return interval, no storage with the 1 year storm? Only get storage for volumes larger than that
    - Larger more infrequent storms have less floodplain reconnection
- Panel Comments:
  - **Solange**: Was skeptical of using wetlands data to project instream N Processing in Protocol 2, noting that wetland removal is greatest during growing season, but may export during fall/winter, no net removal and can lead to overestimation of nitrogen removal Also, wetlands that hold a lot of water can become anoxic, no conversion of ammonia to nitrate, volume of water is not sufficient, need to consider maximum depth
  - **Solange** thought that it might be appropriate to recommend an independent review of Protocol 1.

- Panel: was somewhat skeptical of the "stream as a wetland" approach and that we should review the quality of research studies for both protocol 2 and 3 (issue of riparian buffer vs. palustrine wetland).
- CSN/CWP to come back to the panel with some additional options
- **Bill** to pass along wetland forestry document to panel (via Russ Dudley)
- **Cappuccitti** –asked **Bill** if the Protocol 3 considers floodplain connection at various depths along the stream restoration project, **Bill** felt this was a good point, and suggested it was possible to develop estimates based on each reach
- **Berg** thought it may be too difficult to develop such estimates even with many data points, further discounting not good
- **Deb** suggested adding verbiage to explain how to possibly deal with situations with variable connection depths, e.g. break reach into segments or take an average.
- **Panel**: Both Protocol 2 and 3 may need additional qualifying conditions regarding floodplain reconnection design (min residence time, max ponding depth, defined bank height ratio, etc.
- **Solange**: On Protocol 3, new study from NC show frequency of inundation along floodplain, high frequency of flooding is more important than volume

ACTION: Tom and Bill to put together a draft of supplemental site design criteria to support Protocol 2; other panelists are encouraged to provide their input as Tom and Bill draft the list

ACTION: Tom and Bill to revisit wetland issue for Protocol 2 and check the scientific justification for wetland restoration efficiencies provided in Protocol 3

Rapid Feedback on First Draft of the Final Technical Memo Each panelist was asked to take 3 or 4 minutes to provide specific feedback on what they liked (and didn't like) about the first draft. Their main points are listed below. Due to the number of panelists who were unable to attend the meeting, the Panel decided to extend the comment period until **October 12, 2012**.

- **Dan Medina**:
    - One concern with the use of the word "meaningful" on page 25 in the following statement: "*…applicants should demonstrate that meaningful upland restoration practices and /or stormwater controls are being coincidentally installed*" - how to define meaningful?
- **Josh Burch**
    - Sections 4.1 and 4.2 need to be re-worded
    - Dry channel RSC referred to as Protocol 4 but if RSC is BMP then is it really a separate Protocol?
    - Concerned with Pre/post construction monitoring requirements – should the recommendations give people a choice of what to monitor.May not want to be prescriptive, what to monitor is dependent on objectives

ACTION: Panel decided to omit the monitoring protocol from the document

- **Natalie Hartman**
    - Need better definition of an urban stream
    - Non-urban stream restoration definition needs to be added
    - She was unsure how urban stream restoration ties into MS4 entities

- **Tom** felt it would not be necessary to distinguish stream restoration for MS4 and non-MS4 areas since they are visible enough projects that require so many permits regardless of MS4 classification

- **Steve Stewart** decided to hold his comments until later

- **Lisa Fraley-McNeal**
    - Was curious about how the recommendations will tie into the Bay Watershed Model. **Tom** indicated he would follow up with Matt Johnston from CBPO modeling team about the issue

- **Solange Filoso**
    - Requested that she be allowed to submit her comments to **Tom** and the rest of the panel by email
    - Noted that there are a few studies in Anne Arundel county that the panel could use to validate the approaches (with observed data)

- **Joe Berg**
    - Reiterated his perspective that a meaningful floodplain connection should be considered under Protocols 1, 2, and 3 together.
    - Will work with Bill Stack and Tom on the floodplain reconnection section (Protocol 3) and to forward those edits to **Tom** and the rest of the panel

- **Matt Meyers**
    - Suggested that the a note be made at the end of each protocol regarding meeting local TMDLs
    - Commented that he would send a link to the USGS presentations on the Difficult Run study that was mentioned during the June panel meeting – data will help support the work that the panel is doing
    - **Note:** the Difficult Run presentations have been added to the sharepoint site

November 7th, 2012
Meeting Minutes
Urban Stream Restoration Expert Panel

EXPERT BMP REVIEW PANEL Stream Restoration		
Panelist	***Affiliation***	***Present ?***
Deb Cappuccitti	MDE	Yes
Bob Kerr	Kerr Environmental Services Corp.	No
Matt Meyers	Fairfax County	Yes
Dan Medina	Atkins	Yes
Joe Berg	Biohabitats	Yes
Lisa Fraley McNeal	CWP	Yes
Steve Stewart	Baltimore County	Yes
Dave Goerman	PA DEP	No
Natalie Hartman	WV DEP	Yes
Josh Burch	DDOE	Yes
Robert Walter	Franklin and Marshall	No
Sujay Kaushal	University of Maryland	Yes
Solange Filoso	University of Maryland	No
Julie Winters	EPA CBP	Yes
Bettina Sullivan	VA DEQ	No
Tom Schueler	CSN (facilitator)	Yes
Panel Support and Observers: Jeff Sweeney, EPA CBPO, Matt Johnston, EPA CBPO, Bill Stack, CWP, Jeremy Hanson, CRC, Cecilia Lane, CSN		

MEETING MINUTES

Review/Approval of September Panel Meeting Minutes: Tom Schueler (CSN) began the meeting by thanking all of the panelists for their hard work and their feedback on the technical report.

ACTION: The Panel approved the meeting minutes from September Panel meeting.

Update on Panel Next Steps: Tom briefed the panel on the next steps to get the recommendations approved through the CBP BMP review protocol process, including coordination with Bay modelers, informal review by other experts, and the agricultural work group, and the proposed approach to get input and approval from Urban Stormwater Workgroup, Watershed Technical Work group, the Habitat GIT and the Water Quality GIT. Tom also described how the various technical appendices will be developed.

- 11/20/12 Bay Program Modelers and Scenario Builder Team to make
- Coordinate with Ag Workgroup on non-Urban Stream Restoration recs
- Face-face in December at Fish Shack with USWG and WTWG and members of Ag workgroup
- 30 Day comment period for the states
- After which will be submitted to 3 GITs
- Will be working with CWP to develop the appendices, meeting minutes and technical documentation

- Lisa has volunteered to present recommendations at the workgroup meeting but all panelists would be welcome to attend and participate in the meeting.

Key Changes in Second Draft of Expert Report: Tom went over the key changes in the second draft of the panel report as follows:

- The Hyporheic Box Method: **Bill Stack** (CWP) presented an empirical method for determining N reduction via denitrification during baseflow that was recently developed by Sujay, Bill, Tom and Paul Mayer. This conservative approach defines the geometry of a hyporheic box associated with a stream restoration to which a unit denitrification rate is then applied. The Panel was asked to decide whether this approach is better than the existing Protocol 2 method.
    - **Dan Medina** noted the following:
        - Bank height ratio needs to be clarified
        - Asking for a degree of precision that will be difficult to meet by practitioners
    - **Deb Cappuccitti** asked about the average bulk density conversion rate
        - Tom clarified that an implementer must measure bulk density at each individual site
    - **Joe Berg** asked about the carbon content
    - The Panel generally likes the method, **allow for a 3-day period to establish better qualifying conditions and let Tom know of any questions or concerns**
- Use of Jordan (2007) CBP-approved nutrient removal rates for floodplain wetland restoration projects
- More general approach to stream functional assessment methods
- Reorganized and slightly modified Protocol 1
- Updated curves for floodplain reconnection
- Revised design examples
- Less prescriptive text on pre and post construction monitoring requirements
- *Floodplain Reconnection Criteria for Protocol 3*
    - **Dan Medina** commented
        - Tied to the 1-year event,
        - Floodplain surface area to drainage area
        - Bill to make a recommendation to define extent to floodplain
        - Frequency a component
        - Add a visual representation
    - **Joe Berg** said should remove the residence time condition
        - Surface area wetted and the frequency of wetting
    - **Tom** clarified that trying to prevent a 10-minute inundation of the floodplain qualifying for the credit
    - **Dan** suggested changing the x-axis
- Future research and management priorities
- A six month window to "test drive" the protocols to make sure they can be properly applied by users
    - **Deb** questioned why the extent should be limited to 6 mo
    - **Josh** supports the idea of a timeline approach

DECISION: The Panel decided the Hyporheic Box Method is a suitable replacement for Protocol 2 but will have until Monday, November 12, 2012 to establish any additional qualifying conditions.

Panel Feedback on the Key Changes: Tom asked the panel for their feedback on the second draft of the expert panel report. The following are a few major points that were made:

- Tom noted that sediment reduction had been left out of Protocol 3 due to the lack of existing data.
- Tom asked the Panel if it would be okay to add a sediment credit to Protocol 3
- The Panel noted that at a minimum Protocol 3 should receive credit for sediment removal equal to Protocol 1 but probably should be greater.
- **Matt Johnston** noted that streams should be consistent with the way BMPs are put into the model and recommended a comparison to the interim rate
- **The Panel** decided to create a comparison table that demonstrates the lbs/ft reductions associated with the different Protocols as (either individually or collectively) they compare to the interim rate.

ACTION: Any additional comments/edits on 2nd draft get to Tom/Bill by November 21st. Tom and Bill to put together the Appendices by the December meeting**.**

Panel Feedback on the Final Recommendations: Each panelist was asked to provide final comments on the report by **November 21st** and indicate whether they would be comfortable with endorsing the final recommendations as written, or identify specific changes that are needed to get their support. Based on the feedback, the Panel, as a whole, decided to approve the final report, contingent upon the completion of specific changes requested.

Tom thanked the panel for all of their hard work and commended them on a great set of recommendations and specifically thanked Bill Stack and Lisa for their help on the final recommendations. **Dan** thanked Tom for his leadership on the Panel.

Appendix E Conformity of Report with BMP Review Protocol

The BMP review protocol established by the Water Quality Goal Implementation Team (WQGIT, 2010) outlines the expectations for the content of expert panel reports. This appendix references the specific sections within the report where panel addressed the requested protocol criteria.

1. Identity and expertise of panel members*: Table in Section 1, p. 6*

2. Practice name or title: *Stream Restoration (urban and non-urban)*

3. Detailed definition of the practice: *Section 2.2, p. 9-11.*

4. Recommended N, P and TSS loading or effectiveness estimates
Section 5, Protocols 1 to 4, p. 28-36.

5. Justification of selected effectiveness estimates*: Section 3, p. 15 to 24, with more detail in Appendix B and C*

6. List of references used*: p. 47, and also see Appendix A*

7. Detailed discussion on how each reference was considered*: Section 3*

8. Land uses to which BMP is applied: *All Land Uses that meet qualifying conditions*

9. Load sources that the BMP will address and potential interactions with other practices: *Section 4.1 and Section 4.4*

10. Description of pre-BMP and post-BMP circumstances and individual practice baseline: *See Protocol 1 to 4 in Section 5, and Appendix B and C*

11. Conditions under which the BMP works/not works: *Section 4.1. 4.2 and 4.4*

12. Temporal performance of BMP including lag times between establishment and full functioning. *Sediment delivery ration in CBWM (section 2.5)*

13. Unit of measure: *mass of N, P, or TSS reduced, which depends on project design factors and the applicable protocol(s)***.**

14. Locations in CB watershed where the practice applies: *Anywhere a project meets the qualifying conditions (see Sections 4.1 , 4.2 and 4.4, as well as Section 8.1.*

15. Useful life of the BMP: *5 years, but renewable based on visual inspection (Section 7.1)*

16. Cumulative or annual practice: *Cumulative*

17. Description of how BMP will be tracked and reported: *See Section 7.1*

18. Ancillary benefits, unintended consequences, double counting*: See Section 4.3 on stream functional uplift, Section 7.2 on special issues related to trading and mitigation and section 8.1 Panel's confidence in its recommendations (section 8.1)*

19. Timeline for a re-evaluation of the panel recommendations
2017, see Section 8.1

20. Outstanding Issues

- *Test drive period for protocols (Section 8)*
- *Monitoring, modeling and management recommendations (section 8)*

21. Pollutant relocation: *None at the stream reach scale*