The State of the Science and Practice of Stream Restoration in the Chesapeake: Lessons Learned to Inform Better Implementation, Assessment, and Outcomes

STAC Workshop Report
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About the Scientific and Technical Advisory Committee

The Scientific and Technical Advisory Committee (STAC) provides scientific and technical guidance to the Chesapeake Bay Program (CBP) on measures to restore and protect the Chesapeake Bay. Since its creation in December 1984, STAC has worked to enhance scientific communication and outreach throughout the Chesapeake Bay Watershed and beyond. STAC provides scientific and technical advice in various ways, including (1) technical reports and papers, (2) discussion groups, (3) assistance in organizing merit reviews of CBP programs and projects, (4) technical workshops, and (5) interaction between STAC members and the CBP. Through professional and academic contacts and organizational networks of its members, STAC ensures close cooperation among and between the various research institutions and management agencies represented in the Watershed. For additional information about STAC, please visit the STAC website at http://www.chesapeake.org/stac.

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Cover graphic: Right: Unrestored stream, Crooked Branch, targeted for restoration, Fairfax County, VA. Photo courtesy of Greg Noe, U.S. Geological Survey. Left: Stream restoration along Furnace Branch, Glen Burnie, MD. Photo courtesy of Tess Thompson, Virginia Tech.

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Table of Contents

Executive Summary

The Chesapeake Bay Program's (CBP) Science and Technical Advisory Committee (STAC) organized and led a workshop on the science and practice of stream restoration in order to summarize the state of knowledge in order to identify ways to improve stream restoration outcomes. The workshop identified a general framework for explaining the main factors leading to stream restoration outcomes: stream degradation has occurred, leading to regulatory and policy motivations that prioritize project goals, which leads to restoration approaches, assessment and monitoring efforts, and ultimately stream restoration outcomes. In the Chesapeake Bay watershed, stream restoration often occurs in response to Clean Water Act (CWA) mandates to reduce nitrogen, phosphorus, and sediment loads to the Bay. Reviews of stream restoration outcomes summarized at the workshop showed that, in general, stream restorations have led to minimal improvement to stream aquatic biota, effective 'stabilization' of channel form over time, moderate improvements to water quality, and short-term negative impacts to riparian vegetation.

The fundamental finding of the workshop was that often the primary goal of stream restoration projects is to improve geomorphic stability in the restored reach and downstream water quality, and not to improve local ecological conditions through 'uplift' (improvement of one or more ecosystem functions through a restorative activity; a term defined in Appendix D), and therefore these projects often do not improve aquatic macroinvertebrate or fish communities. This conflict in goals is a shortcoming of the currently most common regulatory driver for stream restoration (reducing downstream loads of N, P, and sediment) that could be addressed directly through diversifying goals to include biotic uplift, as biological benefit is an assumed condition for the permitting and crediting of stream restoration projects. It is also likely that current understanding of stressors and drivers of stream ecosystem health is insufficient, and that reach-scale restoration focused on geomorphic restoration is not removing the actual sources of stream health impairment that may arise in the upstream watershed. More science could help to identify how to improve the ecological condition of streams through management. The outcome of stream restoration monitoring has revealed that while geomorphic and hydrodynamic functions of stream restoration projects may be achieved, biotic stream function improvements remain elusive. As such, ensuring uplift may be achieved by avoiding restoration projects that risk resources in higher-quality streams and riparian corridors. Reach-scale restoration often does not effectively mitigate the watershed-scale stressors of stream ecosystems. If a desired outcome of stream restoration includes ecological uplift, then focusing efforts on improving stream ecology could help meet that goal.

Key findings and recommendations

- **Define Goals** - If improved ecological functions (uplift) are the main goals of stream restoration projects, then explicitly identify those functions and make them a goal, use appropriate restoration design approaches and locations to achieve that goal, and monitor those restoration outcomes.

- **Prioritize Ecological Uplift** - Most stream restoration projects for the Chesapeake Bay Total Maximum Daily Load (TMDL) have the primary goal of nutrient and sediment reduction to the Bay, but do not currently incentivize funding or prioritization for local stream biotic uplift even though biological improvement is a condition of CWA permits.

- **Avoid Harm** - Target stream restoration for locations with more strongly disturbed stream reaches, use approaches that are more likely to address stream ecosystem stressors and generate improved functional uplift, and avoid harming higher quality streams and their riparian zones.

- **Regulatory Restrictions** - Federal Emergency Management Agency (FEMA) Flood Insurance Program (FIP) requirements rules discourage changing (increase or decrease) base flood levels, restricting the rewetting of the riparian corridor and floodplain due to restoration and potentially limiting functional uplift.

- **Assess Outcomes** - Assess the achievement of restoration project goals by using multiple metrics of stream ecosystem health (such as multiple taxonomic groups, ecological processes, human use and engagement, socio-economics, the riparian zone, and functional processes) and a study design to test hypotheses and assess whether project goals and objectives have been achieved.

- **Understand Stressors** - Improved scientific understanding and predictions of stressors to the stream ecosystem at the spatial scale of individual stream reaches can assist in the choice of restoration approaches.

- **How Much Change Is Good?** - Research to identify the optimal amount of dynamic geomorphic change for various stream ecosystem attributes could help restoration designs.

Introduction

Since 2010, jurisdictions throughout the Chesapeake Bay Watershed (CBW) have implemented approximately 266 miles of stream restoration with an additional 84 miles planned as reported in the Phase 3 Watershed Implementation Plans (https://www.epa.gov/chesapeake-bay-tmdl/phase-iii-wips). The extent of project implementation driven by nitrogen, phosphorus, and sediment (N/P/sed) load reductions required by the Chesapeake Bay Total Maximum Daily Load (TMDL) will result in large-scale effects on aquatic ecosystems. Although Chesapeake Bay Program (CBP) expert panels have determined that stream restoration leads to nitrogen (N), phosphorus (P) and sediment load reductions to improve the health of the Chesapeake Bay (Wood et al. 2021), the effects on other local stream ecosystem attributes is less certain. Motivation for restoring streams extends beyond load reductions and can include functional uplift to improve the status of aquatic biota and riparian corridor habitat, geomorphic stabilization to protect infrastructure and property, and additional green spaces in urban areas. Rapid increases in stream restoration implementation throughout the CBW have led to growing concern and controversy about the effects of stream restoration on whole-ecosystem health and services. Although assessment of outcomes of stream restoration projects has been historically limited (Bernhardt et al. 2005; Newcomer-Johnson et al. 2016), over time more studies have documented the results of stream restoration practices, creating opportunity to summarize these new findings.

Purpose

The overall purpose of the workshop was to bring together a diverse cross-section of experts and stakeholders in the field of stream restoration to review and distill lessons learned from past stream corridor restoration projects to improve future restoration outcomes. For the purposes of this workshop, stream restoration was broadly defined as an intervention to move a degraded ecosystem towards a trajectory of recovery as informed by a reference condition considering local and global environmental change. The scope of the workshop included the riparian area and its floodplain. A key theme was relating the current drivers of stream restoration (regulatory, policy, etc.) to identified project goals and measured outcomes.

The past, the present, and the future were chosen as themes to improve our understanding of stream restoration outcomes to enable adaptive management to improve future stream restoration efforts. Invited speakers, synthesis teams, and breakout sessions of in-person and virtual participants focused on these chronological themes in support of workshop goals:

1. Identifying the evolution of stream restoration goals, regulations and practice implementation
2. Presenting and discussing science and assessment to document holistic impacts and outcomes
3. Creating a synthesis of the best available science, practices, and monitoring to enable adaptive management that improves stream restoration activities

Workshop Presentation and Panel Summaries

Session 1: Evolution of stream restoration goals, regulations, practices, and practice implementation (after 1972 Clean Water Act)

The objective of Session 1 was to provide background information on stream restoration in the Chesapeake watershed and help answer these questions:

1. How has management or mismanagement resulted in the impairment of streams?
2. What is our understanding of how stressors influence streams and our ability to appropriately identify and address these stressors?
3. What are the drivers (motivations) for stream restoration?
4. What management has been taken in the past to restore streams?

Notable findings from Session 1 include:

- The geology and history of human use of watersheds and streams has left an imprint on how streams function and their current level of impairment.
- Stream ecosystem functions and responses to disturbance and restoration are strongly influenced by the stream corridor, a connected system of the channel, hyporheic zone, and floodplain. Effective stream restoration manages the entire stream corridor.
- Stream restoration approaches and practices have evolved over time in response to societal values, regulations, adoption of new approaches, increased funding, and improving understanding of stream science.

Watershed History and Evolution of Stream Degradation Patterns and Restoration

– Ellen Wohl (*Colorado State University*), Presentation Slides

Ellen Wohl (Colorado State University) provided the workshop opening plenary entitled, “Watershed Legacies and Their Implications,” Wohl covered the history and evolution of stream degradation patterns and restoration. Streams and rivers and their floodplains and wetlands are connected ecosystems, with great spatial and temporal variability in hydrology, geomorphology, biology, and functions, suggesting a focus on restoration of the entire stream corridor. Figure 1 illustrates the 'Stream Evolution Model', integrating former channel evolution models with additional stages to represent pre-disturbance and late-stage evolution. Dashed arrows indicate 'short-circuits' in the progression, such as Stage 4-3-4 transitions, which can have significant impacts (Cluer & Thorne, 2014). Wohl emphasized the importance of considering the heterogeneity and connectivity of river corridors, as well as their resilience and thresholds. In addition, this presentation discussed the challenges of restoring river ecosystems, particularly in the context of legacy sediment and excess nutrients.

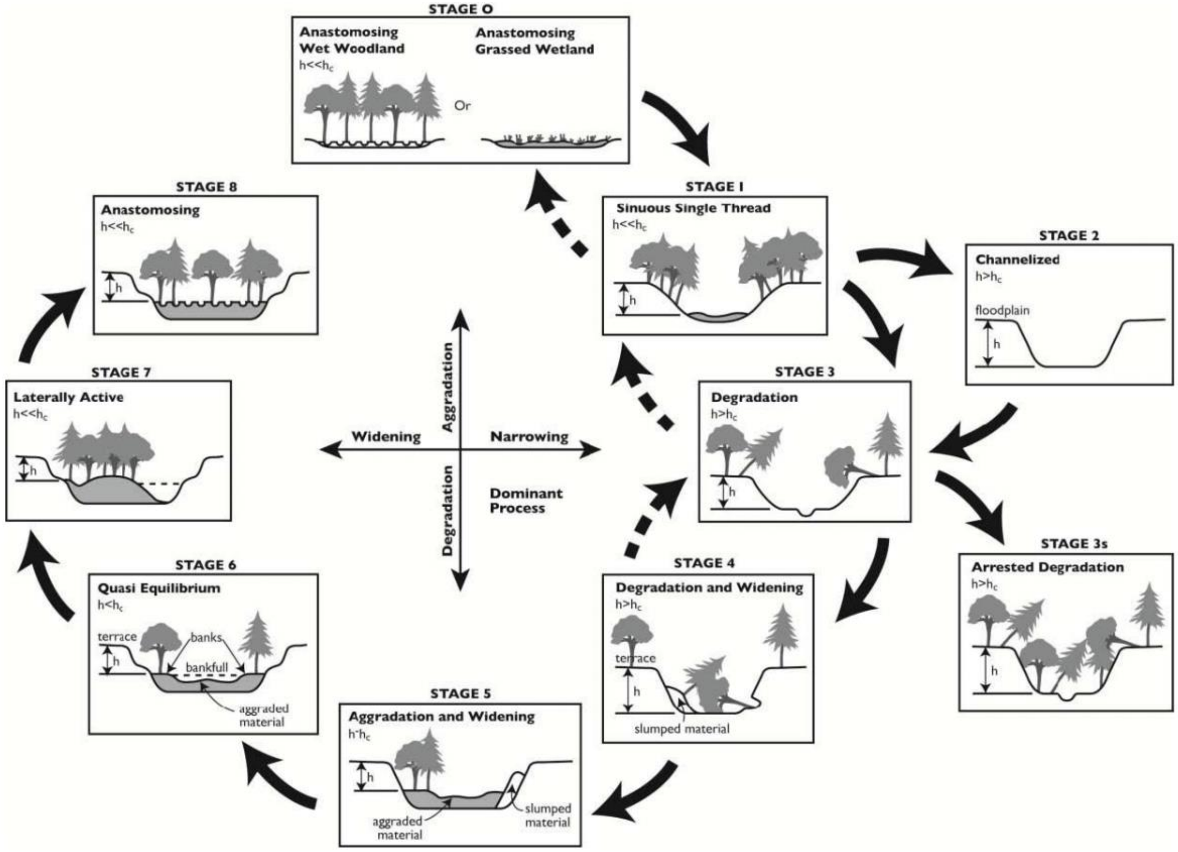


Figure 1. The Stream Evolution Model integrates former channel evolution models with additional stages to represent pre-disturbance and late-stage evolution. Dashed arrows indicate 'short-circuits' in the progression, such as Stage 4-3-4 transitions, which can have significant impacts (Cluer & Thorne, 2014).

River network geometry and interactions with the floodplain vary through time and space, influenced by both natural and human factors. To maintain the health of river ecosystems, Wohl noted the importance of connectivity, resilience, geomorphic integrity, and ecological integrity. Rivers can exist in alternative states, such as a beaver meadow or elk grassland, and can be pushed between these states by disturbances over time. For example, while beavers create wetland habitats in river valleys, supporting willows and other vegetation, elk grazing can lead to beaver decline, by shifting the ecosystem to a drier state. Anthropogenic impacts (i.e. beaver trapping and land cover changes) further alter river corridors. The legacy of these changes includes dams, floodplain wetlands loss, and river restoration efforts.

Stream reference conditions are important for understanding the potential form and function of a river corridor but may not be straightforward or simple to determine due to historical alteration and ongoing climate change. Even in the absence of human impacts, identifying and characterizing reference conditions is challenging due to natural variability and non-stationary systems. Wohl provided examples of how reference conditions may not be feasible or sustainable for current restoration goals, such as when sediment fluxes and hydrogeomorphic context have changed in a manner that precludes a return to reference conditions, including under climate change constraints.

Overall, Wohl emphasized the importance of considering river form and function as a continuum, rather than dichotomizing it into pristine or degraded states. Implications for restoration include a diversity of river form and function, the importance of context (natural setting and human constraints), and recognizing the effects of climate change on river ecosystems such as disturbance, species ranges, and biotic communities.

Panel: The Chesapeake Nontidal Watershed History and Evolution of Stream Degradation Patterns and Restoration

Ben Hayes (Bucknell University) facilitated a discussion with invited panelists on the Chesapeake Bay's nontidal watershed history and the evolution of stream degradation and restoration. Speakers for this session included Dorothy Merritts (Franklin & Marshall College), Karen Prestegaard (University of Maryland), Matt Cashman (U.S. Geological Survey), and Kevin Smith (Maryland Coastal Bays Program). Summaries from each panelist presentation are below.

Changing Views of the River

– Dorothy Merritts (*Franklin & Marshall College*), Presentation slides

Dorothy Merritts led a presentation entitled, 'Changing Views of the River'. As described by Merritts, restoring a valley bottom requires some understanding of the following elements:

- long-term (millennial) climate and geomorphic history of the area
- location of the long-term groundwater table
- nature of the material in which groundwater flows in the valley bottom at present
- ways in which stream channels, floodplains, and wetlands were interconnected during the past few thousand years
- causes of degradation, including those that might have had impacts over centuries (i.e., not just modern land use).

Restoration is often channel-focused and makes assumptions that the modern channel has existed for millennia and degradation along the channel, such as high rates of bank erosion or high-water temperatures, is the direct result of modern land use that can be blamed directly, such as a parking lot at a mall with poor stormwater management that contributes high rates of stormwater runoff from culverts.

Drawing from over two decades of research in the mid-Atlantic region, Merritts showed that the causes of channel incision, bank erosion and poor stream water quality have deep roots extending back centuries. Case studies were presented to document a centennial legacy of sedimentation followed by channel incision along valley bottom corridors.

This talk focused on the example of Little Conestoga Creek in Lancaster, Pennsylvania, where approximately 4 km of valley length including several mill ponds is currently being restored by removing historic (legacy) sediment. The legacy sediment is compromised largely of silt and clay that had been deposited in the slack water upstream of mill dams during the 18th and 19th centuries. Drone video and imagery, as well as photos taken on the ground during backhoe trenching in February 2023 (Figure 2), reveal buried wetlands that span the entire valley bottom, with no evidence of single-thread meandering channels or gravel bars. In other words, the valley bottoms were dominated by a groundwater-fed wetland mosaic with multiple springs and slow-moving shallow, small channels, likely anastomosing, that carried only fine sediment.

Figure 2. Images from Little Conestoga Creek in February 2023 during a restorative effort to rejuvenate about 2.5 miles of the impaired channel. Depth of incision affects access to Pleistocene gravel that generally is stored beneath Holocene sediments. (With Justin Spangler, LandStudies.)

Radiocarbon dating reveals that the formation of the wetlands dates back approximately 11,700 years, coinciding with the onset of warming during the Holocene Epoch. The sedimentology and stratigraphy of the legacy sediment above the dark hydric soil align with slack water deposition, indicating a longstanding history of valley bottom dynamics. Beneath the hydric soil lies poorly sorted rubble dating to the Younger Dryas period, characterized by cold conditions and periglacial processes such as frost shattering, highlighting the persistence of permafrost in the region until approximately 11,700 years ago. Despite millennia of stability, European settlement around 300 years BP (Before Present) catalyzed rapid changes, submerging and burying Holocene wetlands beneath millpond sediment, leading to the eventual incision of modern channels and shifting the focus of stream restoration efforts towards relatively young geomorphic features.

Restoring such streams requires an understanding of the geomorphic history of the valley bottoms and the close linkage between the buried wetlands and groundwater levels. In this talk, Merritts discussed sites where restoration has removed the historic sediment to expose (daylight) the buried Holocene wet meadows, rather than attempt to stabilize incised channels in walls of mud and make them able to transport bedload from Pleistocene deposits.

Urban Runoff and Channelization

– Karen Prestegaard (*University of Maryland*), Presentation slides

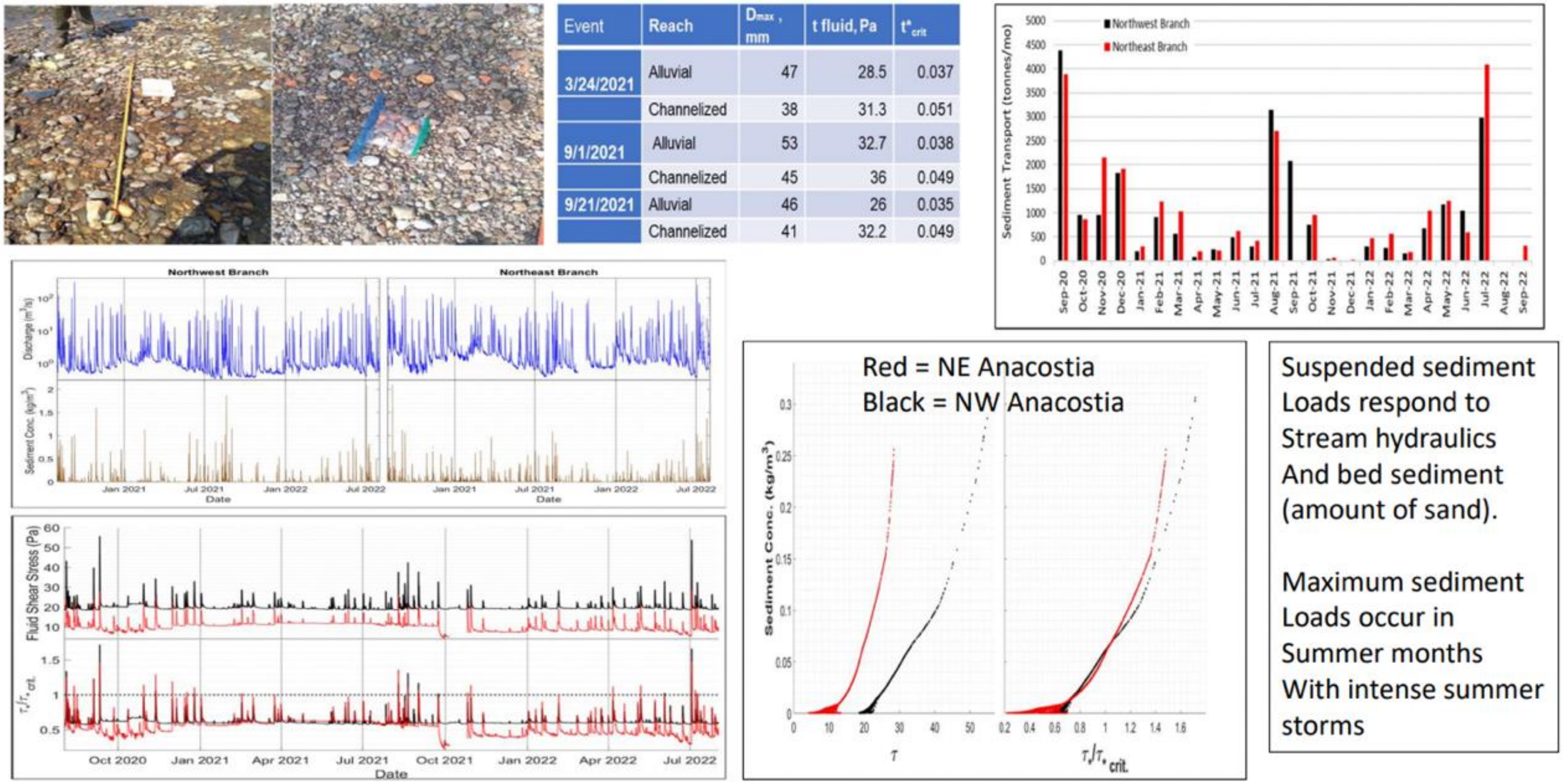
This presentation focused on urban streams near the boundary of the Piedmont and Coastal Plain and their restoration. Increased transport of sand due to construction has changed sediment dynamics and can lead to filling of stream channels that results in reconnection of floodplain. In such cases the stream may be self-healing and not need intensive restoration efforts.

Due to changes in the Pleistocene, these streams are deeply incised and do not have wide floodplains. These streams are often steep and run along a fall line that later, urbanization followed. Major cities in the region are built along these Piedmont Coastal Plain rivers and urbanization has greatly affected these areas. Prestegaard shared data from the Northwest Branch of the Anacostia River in Montgomery County and Prince George's County, Maryland, where streamflow has increased systematically over time as a result of urbanization. In response to the increased streamflow, the stream channels have widened causing bank erosion. This bank erosion has increased sediment fluxes (nearly 70% is fine sediment) in response to flooding, particularly at the Piedmont Coastal Plain boundary. As seen in Figure 3, conveyance channels that connect the steep Piedmont reaches with narrow floodplains to the tidal estuary are used to respond to frequent flooding, allowing gravel and sand to move down to the head of the tide. Further, Prestegaard noted that the sand deposition is often observed at the Piedmont Coastal Plain Boundary forming point bars, as streams transition to the lower gradient bedload.

Figure 3.Urban runoff and channelization increases discharge, bank erosion, and stream hydraulics. Data from the Northwest Branch of the Anacostia River shows discharges increased systemically over time as a result of urbanization.

To evaluate the source of sand, seismic surveys were performed across the stream channels from the uplands. Fast seismic velocities indicate bedrock, while slow seismic velocities mean unconsolidated soil. At the flat upland, soils are deep and incised to bedrock and do not allow for wetlands in the very narrow channel bottoms. From core sampling in the uplands, sandy sub soils were found that become exposed when major road construction occurs across these major tributaries. Sediment loads are monitored downstream of the active construction and further downstream at the boundary location. Observations showed small winter storms did not transport much sediment load from the construction site due to less activity in the winter. In the early construction stage, a major pulse of sediment was detected and decreased as it moved downstream. As the channels widened by a factor of two, very little extra sediment was noted.

A consequence of sand moving downstream is that as it moves from the steeper parts of the stream reach to the more gradual slope lower reaches. The sand goes from being transported in suspension to being transported as bedload. This mobilizes some of the gravel, forming gravel bars that are reattached to the channel and its floodplain. This serves as a self-restoration process where a more incised channel becomes wider and more complex. Figure 4 shows the changes that are imperative to understand, particularly as urbanization continues to impact rivers with different sources of sediment. Experiments were completed to determine the mobility of the bed. Steeper channels have a higher shear stress resulting in small amounts of sand in the bed and overall less mobile. Looking at the Northeast and Northwest branches of the Anacostia, the hydraulics of these channels are now largely controlling sediment transport, and data shows higher intensity summer storm events are associated with the biggest pulses of sediment movement.



Event	Reach	D_{max}, mm	t fluid, Pa	t^*_{crit}
3/24/2021	Alluvial	47	28.5	0.037
	Channelized	38	31.3	0.051
9/1/2021	Alluvial	53	32.7	0.038
	Channelized	45	36	0.049
9/21/2021	Alluvial	46	26	0.035
	Channelized	41	32.2	0.049

Suspended sediment
Loads respond to
Stream hydraulics
And bed sediment
(amount of sand).

Maximum sediment
Loads occur in
Summer months
With intense summer
storms

Figure 4. Figure describes the changing mechanics of gravel transport in the Northwest and Northeast Branch of the Anacostia, including streamflow, sediment, sediment concentration, fluid shear stress, major weather events, and sediment transport. Experiments were completed to determine the mobility of the bed and at what shear stresses and dimensions sediment would mobilize. Due to sand in the bed, the Anacostia is moving at a dimensionless critical shear stress of 0.035, indicating it is more mobile than the average gravel bed river. Major storm events are shown in blue on the top left and typically occur every other week; the brown spokes underneath are pulses of sediment. Loads respond to Stream hydraulics and bed sediment (amount of sand). Maximum sediment loads occur in summer months with intense summer storms.

Although the Anacostia River has an old urban corridor that has shown progressive changes in urbanization over time that has led to increases in streamflow over time, the adjustments of the channel have been relatively episodic. This is due in part to the mobilization of coarse sand into the system that has changed the sediment transport mechanics. This allows the river opportunities to adjust itself to these conditions, as long as space is provided for a channel to migrate.

Chesapeake Nontidal Watershed History and Evolution of Stream Degradation Patterns and Restoration

– Matt Cashman (*U.S. Geological Survey*), Presentation slides

Legacy sediment in the Coastal Plain
The first topic focused on recent work by the U.S. Geological Survey (USGS) in the Coastal Plain of Anne Arundel County, Maryland, that has helped identify that legacy sediment is also a prevalent issue in the Coastal Plain and not just in the Piedmont where much of the work has previously been focused. Historical evidence supports this as formerly deep-water ports were established in areas which are now miles from navigation, and colonial legislation was enacted to address erosion and siltation in these coastal plain areas. Previous studies in the 1950s by L. C. Gottschalk (Gottschalk 1945) have extensively documented how there has been substantial land encroachment into tidal waters due to the deposition of colonial era (legacy) sediment (see Miller et al. 2019). The Paleochannel Project (https://www.aacounty.org/bwpr/ecological-assessment-evaluation/paleochannel-project) completed by USGS identified deep deposits of legacy sediment in Anne Arundel County, beneath current day floodplains, which is often not visible – unlike legacy sediment deposits visible in streambanks in the Piedmont. Precolonial floodplain flora identified through pollen records in sediment cores also identified a different floodplain ecosystem, typified by a mosaic of alder shrub-swamp, possibly influenced by beaver, and evidence of buried bogs ecosystems in some locations.

Multiple instream stressors affecting stream health.
The second topic was a summary of a USGS study published in the Journal of Environmental Management (Fanelli et al. 2022). This talk highlighted the importance of considering multiple instream stressors affecting stream health, and the effects of management actions on specific mechanisms and stressors. Importantly, management actions which focus on the wrong stressors were unlikely to result in ecosystem uplift, and which can help explain much of the cited lack of ecosystem response to stream restorations. The study conducted a literature review of multiple-stressor studies and separately examined the most common stressors affecting ecological life impairments in the Chesapeake Bay watershed. Together, the study provides conclusions about what these lines of evidence suggest regarding management focus on stressors in the region.

Geomorphology and sediment were considered important in both analyses, but this study identified the conflation of several related but independent topics including sediment, bed sediment habitat conditions, reach-scale geomorphology, and physical habitat, which were interchangeably used throughout regulatory, management, and monitoring contexts. This may be a concern, as management interventions might target one, but not all, of these conflated topics, as and they are not always interchangeable. Salinity was identified as being very important in multi-stressor studies, but was very rarely listed on impairment listings. This indicates that salinity is potentially being underemphasized in the region for explaining ecosystem health. Nutrients were commonly listed on state stream impairment listings, but the literature review only occasionally identified nutrients as consistently important outside of agricultural settings. This suggests a possible overemphasis on nutrients compared to its actual effect on stream health or, conversely, that nutrient pollution in urban streams is an understudied aspect of stream restoration effects. Pesticides and organic contaminants were rarely evaluated in all studies, but were considered to be almost always crucially important to understand ecological outcomes. This suggests a large gap in our understanding on pesticides and organic contaminants control on ecological condition of streams in the region, and more monitoring could help to understand its current extent and severity. Flow alteration as a stressor was not typically measured or assessed using robust approaches. Monitoring observations of possible flow disturbance on channel instability often resulted in listings under sediment impairments. Management focus on sediment erosion controls in the uplands may not necessarily address in-channel flow, stability, and geomorphic habitat issues directly, reducing the potential for ecological impact.

Our Waterways: Then & Now

– Kevin M. Smith (*Maryland Coastal Bays Program*), Presentation slides

Hydrologic changes to the landscape of the Mid-Atlantic region have been considerable since Europeans colonized the area. Nowhere is this more evident than on the Delmarva peninsula where modifications, including ditching, dam construction, channelization, drainage and even the construction of new waterways are ubiquitous across the landscape. Comparisons of USGS maps from the late 1800's through present day clearly indicate the scale and scope of work done to drain water from the land surface to the receiving tidal waterways as efficiently as possible.

This change in hydrogeomorphology, along with excessive stormwater discharge and other factors, has aided in the degradation of our terrestrial and aquatic habitats so that nearly 88% of Maryland streams are classified as poor or fair according to the Maryland Biological Stream Survey's Combined Biotic Index (CBI). These poor conditions in our non-tidal streams contribute to the overall poor environmental health of our receiving tidal waters in Maryland's portion of the Chesapeake and Atlantic Coastal Bays.

Restoring the geomorphic and biological integrity of our streams is a critical step in reversing this downward trend. Restoring these stream systems so they are able to replicate historical (pre-colonial) functions – where possible - is critical to this effort. Research in the last 10 years has shown that our historical landscape, particularly our streams and headwater areas, existed in a much wetter environment with waterways that moved at a much slower pace. Replicating these historic characteristics is integral to achieving stream restorations which will provide opportunities for nutrient processing and habitat uplift. Figure 5 shows the successful restoration of Bishopville Pond in Worcester County, MD.. The pond was restored to aid fish attempting to spawn upstream and to improve habitat and water quality in the headwaters of the St. Martin River. The pond, which was created by a dam at the northern tip of what is known as Bishopville

Prong had suffered for years because of pollution filtering down from streams in Delaware. The dam was replaced with a series of ironstone boulders and cobble weirs to safely convey water downstream and effectively allow anadromous fish to move to upstream spawning grounds.

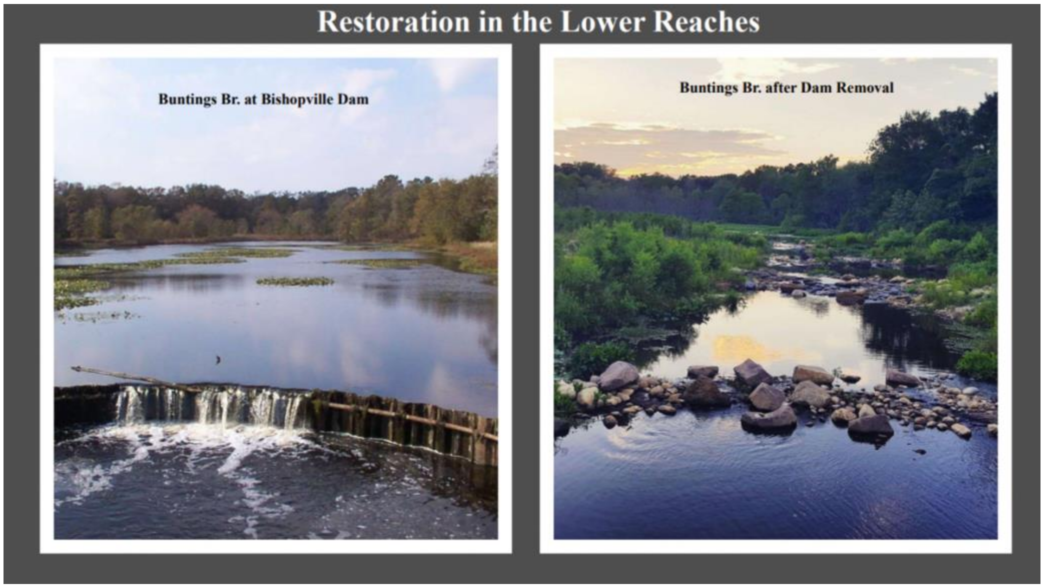


Figure 5. In 2015, Bishopville Dam has been restored after removal of a dam. This was a public-private partnership that was successful in allowing anadromous fish access to upstream spawning areas attempting to spawn upstream and to improving the water quality and habitat in the headwaters of the St. Martins River.

Panel: Outcomes from Stream Restoration in the Past (pre-2014 period of Chesapeake Bay Agreement)

Tess Thompson (Virginia Tech) moderated a session on an examination of past outcomes in stream restoration before the 2014 signing of the Chesapeake Bay Agreement. Two summary presentations were given on 1) Ecology and Water Quality and 2) Stream Stabilization. Following these short talks, three invited experts for both categories joined a panel to answer predetermined and participant questions.

Ecology and Water Quality

– Scott Stranko (*Maryland DNR*), Presentation slides
Ecology panelists, Nancy Roth (TetraTech), Solange Filoso (University of Maryland, Center for Environmental Studies), and Bob Hilderbrand (University of Maryland, Center for Environmental Studies), contributed to this talk presented by Scott Stranko (MD DNR).

Stranko provided a joint summary presentation on Ecology and Water Quality. This presentation underscored the fact that there is not a requirement to return the Chesapeake Bay or streams to the way they were historically. Although, there are CBP goals for reducing sediment and nutrients to Chesapeake Bay, as well as improving stream health, expanding Brook Trout occupied habitat, and protecting state-identified healthy watersheds within the Chesapeake Bay watershed. There are many management approaches being implemented to reduce nutrients and sediment to the Chesapeake Bay.

Focusing on streams, this talk highlighted that one of the primary ways to reduce nutrients and sediment is to slow the water in streams. Slower water results in less erosion, a greater proportion of sediment deposited in or adjacent to the stream channel (rather than downstream); and more microbial processing (to reduce nutrients). However, slower water can risk making stream water quality and biology worse, because it can, (in some cases,) promote deposition of sediment, increase temperature, and lower oxygen. There can be risks to sensitive stream species and attempts to meet CBP stream-related goals may be inhibited. Although a stream may be eroded, it does not necessarily mean the stream is biologically degraded. Overall, reducing streambank and upland erosion benefits the stream and the Bay.

Stream conditions can be improved in certain streams if the limiting factors contributing to impairment are known and can be addressed. However, aquatic species are highly prone to extinction and imperilment. Protecting remaining intact streams is vitally important to species conservation, as well as meeting stream and Bay goals. Speakers encouraged that restoration projects seek restoration approaches that address important nutrient and sediment reduction for Chesapeake Bay without risking sensitive stream resources.

Stream Stabilization

– Rich Starr (*Ecosystem Planning and Restoration*), Presentation slides

In this session, speakers spoke about factors that have influenced stream stability activities from when the Clean Water Act (CWA) was established in 1972, to when the Chesapeake Bay Strategy was established in 2010 (Executive Order 13508, Strategy for Protecting and Restoring the Chesapeake Bay Watershed). The goal of this suite of presentations was to provide context on factors influencing stream stability activities and outcomes and how they evolved over time. Richard Starr provided an overview of factors influencing stream stability projects while Scott Lowe (McCormick Taylor) specifically focused on how stream stability design approaches evolved over time. Bill Stack (Center for Watershed Protection) and David Wood (Chesapeake Stormwater Network) spoke on how water quality improvement requirements (e.g., TMDL reductions) influenced stream stability activities.

Rich Starr presented an overview of factors influencing stream stability activities (“drivers”) and their outcomes. The primary driver in the 1970’s and 80’s was water quality improvement, which was directly related to the Clean Water Act (CWA). Streams during this time period were viewed more as a resource to meet anthropogenic needs (industry, water supply, agricultural, mineral extraction, irrigation, transportation, waste disposal, etc.) or a threat to human lives and livelihood and needing floodplain control. Most stream related activities involved channel hardening and water quality point discharge improvements, resulting in tremendous instream water quality improvements, but low overall ecological uplift between the stream and riparian corridor.

In the 1990's, a shift in stream values started to occur where ecological uplift was becoming an issue of concern. The primary drivers were still similar to the 1980's effort to improve water quality, but stream mitigation and voluntary restoration also became drivers. This resulted in new stream restoration design methods (e.g., Natural Channel Design) that emphasized restoring stream functions. However, the focus was more on the stream channel stability and less on biological uplift and floodplain habitats. Regardless, improvements to ecological uplift started occurring.

In the 2000's, several changes occurred that significantly influenced stream stability activities and stream ecological outcomes. In 2008, a new regulation was established by EPA that required mitigation activities to be based on ecological function. Stormwater management regulations were being updated and design approaches (e.g., legacy sediment removal, beaver analog, base-flow channel, etc.) started to become more process-based and looked beyond the stream channel and included the adjacent floodplains. Lastly, in 2010, the Chesapeake Bay Strategy was established, which centered on a collaborative effort to improve water quality within the Bay. After this point the primary drivers were mitigation, water quality improvement, voluntary habitat restoration, and dam removal. As a result, the ecological outcomes of restoration were the highest they have ever been compared to the past.

Stream Stabilization panelists: Scott Lowe, David Wood, Bill Stack

Scott Lowe (*McCormick and Taylor*)
Scott Lowe started with a description of the evolution of stream restoration approaches and practices, from hydraulics, to channel evolution, to channel stabilization, to natural channel design, to softer structures, to floodplain reconnection.

Bill Stack (*Center for Watershed Protection*)
Bill Stack outlined how prior to the sediment and nutrient TMDLs being issued to the Bay States in December 2010, municipalities could receive sediment and nutrient reduction credits for the implementation of stream restoration projects. The credit was developed by the CBP and was based on limited data. Most stream restoration projects at that time were implemented as part of Municipal Separate Storm Sewer System permit (MS4) plans or mitigation purposes and not to achieve the Chesapeake Bay sediment and nutrient reduction credit.

To meet the challenges of the TMDLs, the CBP developed a robust crediting process that would enable all source sectors (agricultural, urban, forest) to develop crediting protocols for upland Best Management Practices (BMPs) using a consistent robust peer-review process. Once a BMP crediting protocol is developed, there is an extensive review process by multiple CBP work groups (e.g., Urban Stormwater Work Group, Watershed Technical Work Group, and Water

Quality Goal Implementation Team).

In 2012, the CBP tasked Bill Stack and Lisa Fraley-McNeal (Center for Watershed Protection and CBP Sediment and Stream Restoration Coordinator), and Tom Schueler (Center for Watershed Protection and Urban Stormwater Coordinator) to develop a new sediment and nutrient crediting protocol for stream restoration projects using the new CBP protocol. Following the CBP's Crediting Protocol, a panel of experts was assembled, and numerous meetings were held over a two-year period. The panel of experts met numerous times and reviewed over 100 technical and journal articles.

The Expert Panel first determined that the existing crediting protocol was extremely low compared to numerous monitoring studies in the literature. The Panel also decided that sediment and nutrient removal associated with stream restoration occurs through three processes and developed crediting methodologies (protocols) for each one based on the literature and scientific/engineering judgment reached by consensus.

> *Protocol 1* - The first is the prevention (reduction) of sediment and nutrients bound to the sediment associated with stream bank erosion
>
> *Protocol 2* - The second process is associated with denitrification that occurs when stream restoration reconnects the bed of the stream within the floodplain hyporheic zone
>
> *Protocol 3* - The third is the sediment and nitrogen removal that occurs through reconnecting the riparian wetland system to the floodplain

A default credit system was developed based on literature values that could be used for planning purposes and for older projects that could not conform to the CBP reporting process.

The final Expert Panel Report was approved in 2014 (Berg et al. 2014) and included Qualifying Conditions, and, Verification and Reporting Requirements. With the development of the protocols, stream restoration soon became one of the most common BMPs to implement because of its cost-effectiveness, particularly in watersheds that had limited opportunities for upland stormwater BMPs.

During the years following the development of the 2014 Protocols, the Stream and Sediment Coordinator and Stormwater Coordinator received numerous suggestions for how to improve the protocols. There was also concern that the default credit was being used too much instead of the more robust protocols, and that qualifying conditions were not being met. This set the groundwork for the upgrades to the protocols which occurred between 2019 to 2021 (Wood et al. 2021).

David Wood (*Chesapeake Stormwater Network*)
David Wood pointed out that, as the field of stream restoration evolved, a need arose to update the Chesapeake Bay Program's protocols for calculating nutrient and sediment reductions from these practices to reflect the state of the science. In 2018, the Chesapeake Bay Program's Urban Stormwater Workgroup convened over 80 stream restoration researchers and practitioners and kicked off a 3-year effort to revisit the 2014 Protocols. The resulting recommendations focused on four key themes:

- Update Protocols 2 and 3 to reflect the field's improved understanding of floodplain dynamics and emphasis on restoration approaches increasingly focused beyond the channel.
- Require and provide more guidance for how site-specific monitoring should be used to improve estimate nutrient and sediment reductions. This included eliminating pound/linear-foot default reductions for urban stream restoration practices; providing more detailed procedures for collecting bulk density and soil nutrient concentration data; and outlining how to conduct and report post-restoration monitoring to justify improved efficiencies.
- Further emphasize the importance of qualifying criteria and best practices to avoid unintended consequences from stream restoration projects that are improperly placed or designed.
- Develop a method to aid practitioners in the long-term inspection and verification of stream restoration projects.

The protocols were finalized and published in 2020 (Chesapeake Stormwater Network 2020), and updated in 2024. The updated publication entitled, A Unified Guide for Crediting Stream and Floodplain Restoration Projects in the Chesapeake Bay Watershed, can be viewed online here (Wood et al. 2024).

Lessons Learned from the Past

Ben Hayes (*Bucknell University*), Presentation Slides
Hayes summarized the first workshop session and provided a hydrogeomorphic perspective of watershed and stream processes and restoration. In this presentation, Hayes emphasized that successful restoration requires effective knowledge transfer between researchers and practitioners, such as what occurred during this workshop.

The geologic past influences current stream conditions. For example, glaciation had large effect on the shape of, and water energy in, the stream corridor. Time scales matter; for example, some stream geomorphic responses occur over millennia, others occur over days. Functional process zones of streams suggest that local patch dynamics of the stream reach to be restored matters for how to restore that reach. Sometimes there are thresholds of stream response that make management or restoration difficult with unpredictable outcomes. Past stream use (mill dams, logging, etc.) use has left a long-term disturbance that should be considered when restoring streams. Groundwater clearly has a large role in stream functions and responses to restoration but is poorly understood, including in the hyporheic zone. Five take home points:

1. Social and ecological systems are coupled, but far from being in equilibrium.
2. Streams are characterized by thresholds, multiple states, and surprising phenomena.
3. Cross-scale interactions happen between ecological and societal systems, and should be recognized and anticipated (Figure 6).
4. Sometimes streams have slowly evolving conditions.
5. Short-term management measures do not resolve persistent, chronic problems, nor can they deal with continuous change.

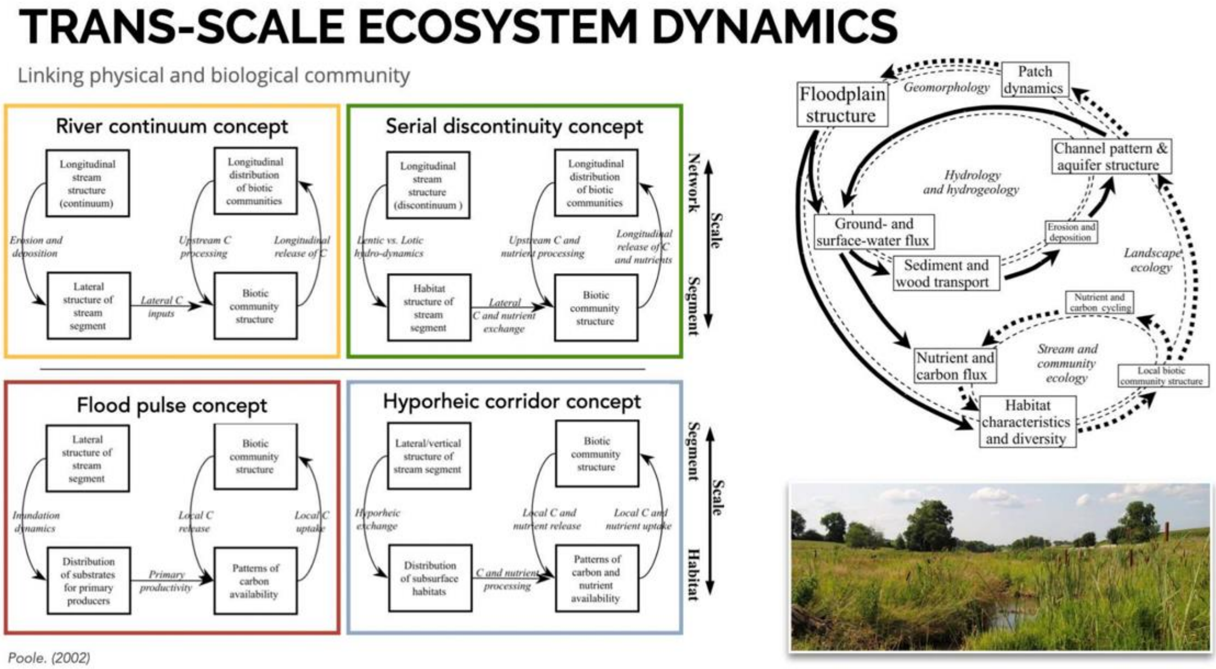


Figure 6. Cross-scale interactions happen between ecological and societal systems and are relevant to stream restoration. *https://www.chesapeake.org/stac/wp-content/uploads/2023/04/Hayes-Ben-Lessons-Learned-from-the-Past.pdf*

Perhaps the ‘sweet spot’ for stream restoration in the Chesapeake Bay watershed is to focus on where local stream impairment can be targeted for restoration efforts under the Chesapeake TMDL. To do this, the project designer would need a better understanding of what stressors to the stream are limiting stream functions. In addition, it is critical to ask “what are the most appropriate reference conditions for regional streams?”

Science/Assessment to Document Holistic Impacts and Outcomes

Session 2 Objective: What are we doing now? What have we seen not go so well? What has been a “success”? What are common regulatory/policy, trade-offs, and unintended consequences (looking at both obstacles and opportunities)? What is the research telling us?

Regulatory/Permitting and Policy: Parameters for Showing Success

Bill Starr introduced a series of presentations from Bay states on current regulatory and permitting processes, voluntary efforts, and how they drive stream restoration goals. Speakers for this session included Denise Clearwater (Maryland Department of the Environment), Brock Reggi (VA Department of Environmental Quality), and Jeffrey Hartranft (PA Department of Environmental Protection).

Maryland – Denise Clearwater (MDE), Presentation slides

The Maryland Department of the Environment (MDE), Wetlands and Waterways Protection Program regulates activities in tidal waters and tidal wetlands, nontidal wetlands and their buffers and expanded buffers, and streams and their 100-year floodplain. The agency reviews discharges under federal permits and/or licenses for compliance with state water quality standards under Section 401 of the Clean Water Act. Furthermore, MDE reviews federal actions for consistency with the Maryland Coastal Zone Management Program. The authorizing statutes were adopted decades apart: Waterways and Floodplain (1933), Tidal Wetlands (1970), and Nontidal Wetlands (1989). Authorization is needed from MDE under the Waterways and Floodplain regulations for activities that change the course, current, or cross section of a waterway or its 100-year floodplain. A key provision is that the decision will be in the best interests of the state. Other considerations are to prevent increases in upstream or downstream flooding, maintain fish habitat and migration, protect waterways from erosion, whether there will be harm to a State Scenic or Wild River, whether there will be a blockage to fish passage, likelihood of loss of life or high value property due to a dam failure, and habitat.

A wide range of activities are regulated under the Nontidal Wetlands Act and regulations. Activities include filling, draining, excavation, grading, alteration of water levels and destruction or removal of vegetation. Activities are also regulated in the nontidal wetland 25-foot buffer or 100-foot expanded buffer.

There are no specific or different provisions for stream restoration projects in statutes or regulations. Impacts have generally been considered to be temporary. MDE attempts to issue authorizations within 90 days by policy. MDE has assigned dedicated staff to review stream restoration projects to expedite review. There has been limited post-authorization follow up of projects.

The most common types of stream restoration projects have been natural channel design, then regenerative stormwater conveyance, beaver dam analogs and legacy sediment removal. Stream restoration can be controversial, with complaints such as: the length of the regulatory process, the excess of trees lost, resource tradeoffs, and issues with increased flooding.

Studies of restoration projects have shown mixed results. Depending on the design and site location, any project type has the risk of resource tradeoff considerations and unintended consequences. MDE generally does not favor restoration to pre-colonial conditions as the sole justification for a restoration project, with rare exceptions. Pre-colonial conditions are generally considered to be non-sustainable in Maryland's highly altered landscapes. Habitats which are currently valued at present are described as Key Wildlife Habitat Types under the Maryland Wildlife Action Plans. Most nontidal floodplains/wetlands are recommended to be forested. Multi-thread channels are not excluded, but the dominant community should remain forested. In urban areas, riparian forest may be the majority of the remaining forest in the watershed.

Information required for review includes the following: project's goals and objectives; project narrative and justification; alternatives analysis; hydrologic and hydraulic analysis; notification/permission of adjacent property owners; wetland determination/delineation; and resource condition assessment.

MDE has undertaken several actions to address concerns about unintended consequences and adverse impacts from stream restoration projects. These include:

- Developed a new checklist for reducing forest loss. Additional information includes a forest stand delineation of larger trees and minimization of impacts:https://mde.maryland.gov/programs/water/WetlandsandWaterways/PermitsandApplications/Pages/nontidal_permits.aspx
- Participated in Chesapeake Bay Program effort evaluating Ecosystem Crediting
- Participated in Chesapeake Bay Program Effort for maintaining forests in stream restoration projects
- Prepared new guidance funded by EPA grant for stream wetland complexes. This was completed in 2021 and is applicable to the Upper Coastal Plain. A similar project underway for Piedmont and Lower Coastal Plain was completed in 2023: https://mde.maryland.gov/programs/water/WetlandsandWaterways/Pages/Stream-Wetland_NewGuidance.aspx

In 2022, new legislation was passed requiring MDE to produce a study on ecological restoration and permitting by June 2024. The deadline has since been extended and completion is expected to be later in summer 2024. Existing laws, regulations, and the permit process will be evaluated, as well as opportunities for public comment, a definition for "ecological restoration," and a separate permit process for restoration projects.

Virginia – Brock Reggi (VA DEQ), Presentation slides

Stream restoration is primarily utilized for credit generation in two programs within the Virginia Department of Environmental Quality (VA DEQ). The VA DEQ regulates both surface and ground waters in Virginia under the Virginia Water Protection (VWP) Permit Program, which is the state counterpart program to the USACE and USEPA Clean Water Act Section 404 permitting. VA DEQ also regulates state waters in accordance with Clean Water Act Section 402 requiring permits to limit point and non-point source discharge of pollutants to streams, rivers, and bays, under the Virginia Pollution Discharge Elimination System (VPDES) Program. The Code of Virginia (§ 62.1-44.15:20) requires no net loss to stream function under the VWP Program, which is sometimes offset by stream restoration derived compensatory mitigation crediting. Stream restoration derived nutrient crediting is discussed in the Code of Virginia § 62.1- 44.19:21. Permitting for all stream restoration projects falls under the jurisdiction of the state VWP Program and federal Clean Water Act Section 404 in Virginia. Most stream restoration projects apply for a US Army Corps of Engineers Nationwide 27 permit, on which the VWP Program provides a conditional Section 401 Water Quality Certification.

Stream restoration in the past primarily offset impacts to streams through the VWP/404 permitting processes in Virginia, but VPDES driven stream restoration projects have increased significantly over the last decade. This increase in VPDES stream restoration projects in Virginia resulted from the Total Maximum Daily Load (TMDL) requirements set by the EPA to reduce sediment and nutrient loads delivered to the Chesapeake Bay. For localities within the state with limited financial resources, Virginia may provide matching state funding to localities to help offset the cost of a stream restoration project, through the Storm Water Local Assistance Fund (SLAF) to meet required nutrient reductions to the Chesapeake Bay. Stream restoration is also utilized in the state for voluntary projects, but much less frequently.

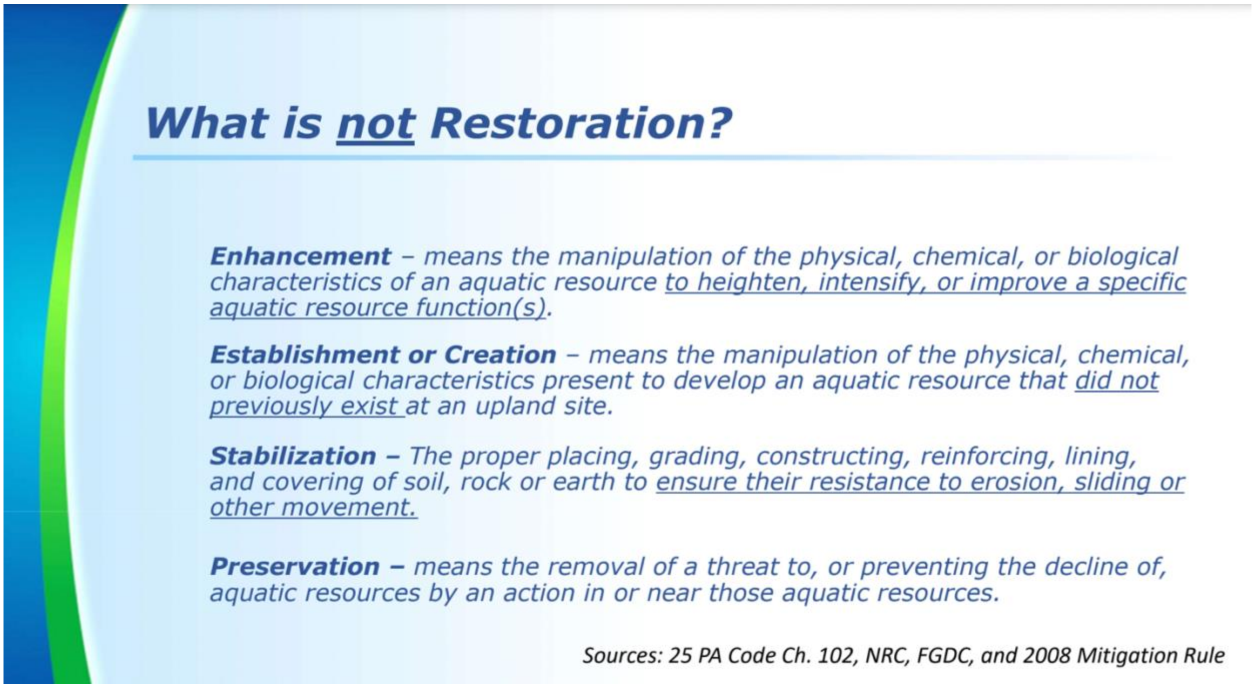
Goals for stream restoration in Virginia have historically included physical channel stabilization, improved aquatic life habitat, preservation and restoration of riparian buffer/corridors, sediment load reduction, and nutrient reduction. These goals are primarily focused and obtained on site specific project areas. Although offsite and downstream benefits are anticipated on VWP stream restoration projects, they are not currently tracked or calculated. On the other hand, VPDES stream restoration projects show site specific improvements through required monitoring plans and downstream benefits in calculated reductions in delivered sediment and nutrient to the Chesapeake Bay.

Stakeholders for stream restoration in Virginia include federal, state, and/or local government, tribal communities, non-government organizations, public sponsors, and private sponsors. Permitting of stream restoration in Virginia requires the Natural Channel Design stream restoration methodology for design at the Federal and State permit levels. However, as the practice of stream restoration continues to increase in frequency across the state, other stream restoration methodologies are being reviewed and accepted in the appropriate valley types. To date, other methodologies being reviewed include Beaver Dam Analogs, Legacy Sediment Removal, and Stage 0 approaches. Combinations of approaches are also being considered, along with the development of new or alternative goals and objectives, performance standards, and monitoring requirements to validate the success of these projects long term.

Common problems associated with stream restoration in Virginia include the following: restrictions on post-restoration water elevation rise in 100-year floodplains; tree loss during construction in urban watershed stream restoration projects; quantifying efficiency increases to nutrient credits derived from stream restoration; limited access to the most impaired stream reaches for watershed scale approaches or projects; and performance standards and monitoring requirements for less common stream restoration approaches.

Pennsylvania – Jeffrey Hartranft (PADEP), Presentation slides

The Pennsylvania Department of Environmental Protection (PADEP) recognizes the federal definition of restoration provided in the Army Corps of Engineers Mitigation Rule (ACE, 2008), and state regulatory programs evaluate projects for their fidelity to this definition. Restoration practices that result in the manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former or degraded aquatic resource have been demonstrated to be the most successful. Key qualifying criteria includes demonstration of site degradations and project objectives that eliminate them. Projects that result in enhancement, creation, preservation, or stabilization (as defined in Figure 7) do not meet the definition of restoration adopted by PADEP regulatory programs.



What is not Restoration?

Enhancement *– means the manipulation of the physical, chemical, or biological characteristics of an aquatic resource to heighten, intensify, or improve a specific aquatic resource function(s).*

Establishment or Creation *– means the manipulation of the physical, chemical, or biological characteristics present to develop an aquatic resource that did not previously exist at an upland site.*

Stabilization – *The proper placing, grading, constructing, reinforcing, lining, and covering of soil, rock or earth to ensure their resistance to erosion, sliding or other movement.*

Preservation – *means the removal of a threat to, or preventing the decline of, aquatic resources by an action in or near those aquatic resources.*

Sources: 25 PA Code Ch. 102, NRC, FGDC, and 2008 Mitigation Rule

Figure 7. Definition of Enhancement, Establishment or Creation, Stabilization, and Preservation as outlined in this document follows the guidelines and criteria established in 25 PA Code Ch. 102, NRC, FGDC, and the 2008 Mitigation Rule.

In the past, conventional stream restoration, also known as "Natural Channel Design," and hybrid approaches have been observed to not perform well. These methods often fail to consider the historic context and degradations, neglecting to recognize and remove site-specific issues such as legacy sediment and other pervasive watershed alterations. Additionally, appropriate aquatic ecosystem reference analogs, particularly those adjacent to the channel, are frequently overlooked. There is often an imbalance between focusing on channel forms without consideration of processes, or vice versa. Water quality is commonly set as the goal without explicitly addressing the underlying degradation. Consequently, project goals often do not meet the true definition of restoration.

PADEP acknowledges that projects developed in accordance with Principles for the Ecological Restoration of Aquatic Resources (USEPA, 2000) provide the most successful restoration outcomes. The use of natural reference analogs, particularly in-situ reference forms and processes that are identified from historical information, are essential to ensure natural forms and processes are appropriately restored. The hypothesis that paleo-reference forms and processes are applicable to modern restoration efforts have not been disproven by researchers in Pennsylvania, and evidence of their applicability to restoring natural aquatic ecosystems is overwhelming (USEPA, 2000). Projects that focus on restoring aquatic ecosystem processes and forms consistent with the reference analogs, particularly hydrologic processes and connectivity (lateral, vertical, longitudinal), are the most successful and resilient restoration projects that provide multiple benefits. One specific example of applying the USEPA Restoration Principles (USEPA, 2000) is legacy sediment removal projects that result in natural functioning aquatic ecosystem forms and processes, including integrated wetlands, streams, and floodplain aquatic resources.

Detailed Case Studies of Individual Stream Restoration Projects

Bill Starr moderated a session that provided detailed case studies of evaluations of individual stream restoration projects. Four speakers outlined different common “types” of stream restoration projects within the Chesapeake Bay Watershed. The goal of these presentations was to provide context for varying approaches to stream restoration and their outcomes, while noting the diverse landscape among the projects.

- Legacy Sediment Removal – Robert Walter (Franklin and Marshall College)
- Coastal Plain – Joe Berg (Biohabitats)
- Urban – Josh Burch (DC Department of Energy & Environment)
- Suburban – Chris Ruck (Fairfax County)

Each speaker described the following causal chain to evaluate stream restoration outcomes, detailing the: landscape setting and stream impairment of interest; regulations and/or policy drivers of the project; defined goals of the project (if any); design approaches and/or restoration practices; monitoring of the activities; and outcome(s) of the project.

Legacy Sediment and Removal

– Robert Walter (*Franklin and Marshall College*), Presentation Slides

Robert Walter (Franklin and Marshall College) presented on improving stream restoration practices, with a focus on Big Spring Run in Lancaster County, PA. The topics covered included diagnosing the problem, regulatory landscapes, restoration design & goals, monitoring results, and scaling up. Mid-Atlantic streams with high banks are not natural, resulting in part from the effects of historic mill dam and pond construction (Walter and Merritts 2008). Such streams and their buried floodplains are sources of sediment and nutrient loads (Forshay et al. 2022). Legacy sediments typically bury pre-settlements wetlands, and these buried wetland soils bear evidence for stable and resilient wetland conditions for the last 10,000 years. Removing legacy sediments reduces a prominent source of suspended sediment and nutrients to streams and the removal creates the hydraulic conditions necessary to restore the buried wetland ecosystem. It also creates an accommodation space for frequent flooding to interact with emergent wetland vegetation, which are optimal conditions for carbon and nutrient retention, including and especially denitrification. As described by Walter, the restoration target is exposing buried wetland soil.

The Big Spring Run restoration began in September 2011, with the design objective of restoring the ecological potential of the stream (Figure 7). Other goals included reducing sediment and total P loads, increasing surface water retention time on floodplain, adding dissolved organic carbon (DOC), attenuating flows, and reconnecting the floodplain wetland with surface water and groundwater.

Big Spring Run Pre-Restoration 4-8-05 **Big Spring Pre-Restoration 4-5-09**

Big Spring Run Post-Restoration 4-30-12 **Big Spring Run Post-Restoration 8-12-16**

Figure 8. Pre- and post-restoration images of a legacy sediment removal stream restoration near Lancaster, Pennsylvania (Sep-Nov, 2011). The pre-restoration stream length was 2,731 ft and after, 2,960 ft. Restoration design and figure adapted from LandStudies, Inc., Lititz, PA.

The restoration design was based on a better understanding of the mechanisms responsible for the origin and stability of natural landscape patterns. The landscape-scale experiment enabled PA DEP to assess whether this new restoration approach would optimize ecosystem function and restore ecosystem services. Long-term monitoring was used to determine whether restoring floodplains and riparian wetlands would improve hydro-geomorphic conditions, ecosystem services, and water quality. The design criteria required flows greater than normal spring base flows to be conveyed through the floodplain. Woody material was placed within the channel to increase the water surface elevation during base flow and legacy sediments were excavated and removed from the valley bottom. Channel plan form was based on increasing flow retention and flow exchange from the channel into the adjacent hyporheic zone and across the valley bottom. Stumps and woody material were frequently placed within the channel and floodplain to provide additional denitrification potential, habitat and base-flow grade control.

The restoration design stream length was 2,731 feet, shorter than the final design length of 2,960 ft (PA DEP). Overall, there was 21, 955 tons of sediment removed, 85-100% of which came from the banks. A total of 4.7 acres of surrounding wetlands were restored. The restoration experiment at Big Spring Run showed substantial reductions in suspended sediment and phosphorus loads, and improvements in carbon storage and denitrification potential (Forshay et al. 2022). Additional benefits include improved aquatic ecosystem services, frequent overbank flow across a broad, low wetland floodplain, flood attenuation;, groundwater recharge, surface water temperature modulation. Legacy sediment mitigation retains a substantial cost advantage for sediment and phosphorus reduction, and is competitive for nitrogen abatement, in comparison to low-cost agricultural practices (Fleming et al. 2019). The improved biological indicators were a shift from an upland, invasive dominated to an aquatic ecosystem dominated plant community. According to Walter, fish, birds, diatoms, and amphibians show increased species richness and diversity post restoration.

Keys metrics twelve years post-restoration are below. These benefits are understood anticipated to continue to improve as the 4.7 acre restored wetland ecosystem matures. Wetlands are 32x more efficient at storing carbon than forests according to data published by Longbottom et al. (2022).

For this project, it was found that organic carbon storage doubled in 10 years (F&M). Key monitoring outcomes from Big Spring Run are listed below.

- Legacy Sediment Removed: ~22,000 tons (F&M and LandStudies)
- Sediment Source: 85-100 % from banks (F&M/USGS)
- Sediment Load Reduction: 600 tons/yr (71% USGS/F&M)
- Total P Removed: ~50,500 lbs (F&M) (79% - USGS)
- Total N Removed: ~63,600 lbs (F&M)
- Increased Denitrification Potential: Shift: carbon-starved to high C:N denitrifying ecosystem (EPA)
- Nitrate Reduction (surface water & groundwater): 12-23% (EPA)
- Total Soluble Reactive Phosphorus (SRP) Reduction in surface water: 37% (EPA)
- Surface Water Temperature: Temperature modulation (F&M)
- Water Storage: 2.7 million gallons annually (USGS – tentative)
- Up/Down Peak Storm Delay in flow: ~17 min increase (USGS – tentative)

Coastal Plain – Joe Berg (Biohabitats), Presentation Slides

Stream restoration has diversified and improved since Natural Channel Design (NCD), developed in the montane environment, was brought east by Dave Rosgen (Wildland Hydrology) and Jim Gracie. Today, many stream restoration practitioners rely upon a diversity of stream restoration approaches to tailor their stream restoration design to site conditions, project goals, and various constraints. Design practices that started in a particular area or landcover, like legacy sediment removal, can be applied in diverse landscape settings and in portions of projects where this stream restoration approach is the optimal solution to a reach or project goal.

Similarly, the use of wood structures applied initially in Maryland in broad forested floodplain areas can be applied more broadly to reduce costs, implement more and larger projects, and support biodiversity goals associated with dynamic stream self-organization as well as other societal goals. This practice has been used for decades in the Northwest and is currently being implemented in Utah and other western states in recognition of the need to develop tools that can be broadly applied by volunteers and non-governmental organizations at a fraction of the typical cost of stream restoration.

Generally, the stream restoration community of practice is converging toward restoration designs that reconnect stormwater-dominated channels to their riparian, floodplain, and stream corridor. These efforts are designed to increase the surface area of the land that pulsed stormwater runoff comes in contact, in order to 1) attenuate energy and peak discharges, 2) reduce runoff volumes, transport of nutrients, erosion and sediment transport, and 3) improve aquatic habitat and deliver a variety of additional societal and ecological values.

As an element of these converging approaches, stream channels are being built to a size to support better aquatic habitat during periods of baseflow. Rarely are oversized channels that only have an inch or two of water during baseflow being designed. Groundwater resources are being restored through increased capture of stormwater in the stream corridor and changing the morphology of the stream channel away from an incised ditch condition to a smaller baseflow-type channel. As a consequence, water surface at the top of the stream bank during spring baseflow ensures frequent floodplain reconnection, more frequently saturating/inundating the floodplain, improving water quality. This approach reverses the ongoing regional trend towards seasonal loss of perennial flow, if only incrementally, by extending perennial flow later into the summer and fall.

Stream restoration is variously implemented for sediment and nutrient reductions, improvement of biological resources, protection of infrastructure and property from the adverse effects of channel erosion and channel migration resulting from our watershed development practices (agricultural as well as commercial and residential). ‘Restoration’ is a broad term open to misinterpretation. Engineering with nature, ecological engineering, green infrastructure, regenerative design, and sustainable design are all relevant and equally problematic terms that can be applied to various approaches currently being used to restore degraded stream resources.

As a community, stream restoration practitioners, regulators, resource agencies, and researchers, are supporting the refinement and improvement of stream restoration. Only two decades ago, open channel conveyance relied on gabion, rip-rap, and concrete trapezoidal channels as the BMP. Then came Natural Channel Design. Now, opportunities are presented by mixing and matching elements of Natural Channel Design, and newer practices such as legacy sediment removal, integrated stream and floodplain restoration, baseflow channel design, regenerative stream design, and more, all focused on delivering the best possible stream restoration projects to optimize the largest benefit. Evolution of the practice of stream restoration to further the ecological values is ongoing, while reducing unanticipated adverse impacts and the time required for recovery from short-term implementation impacts.

Urban – Josh Burch (DOEE), Presentation Slides

Josh Burch (DOEE) presented on the successes and challenges of executing stream restoration in highly urbanized areas by the DC Department of Energy & Environment (DOEE). For over a decade, DOEE has implemented stream restoration projects using Natural Channel Design, Floodplain Reconnection Design, and Regenerative Stream Design. DOEE is not committed to any specific stream restoration technique and works with project partners to develop a clear set of project goals that are calibrated appropriately to fit the site constraints and potential.

Burch highlighted lessons learned from the Natural Channel Design restoration at Watts Branch in Prince George County Maryland. Some positive aspects of Natural Channel Design are that it is generally stable, allows for canopy regrowth, improves fish habitat, and has an overall relatively low material cost. Lessons learned were that small failures can be catastrophic to the design and invasive plants are common. Bankfull, the water level at which a stream is at the top of its banks, is not a good determining factor as the floodplain is often too narrow. Beavers returned to Watts Branch after the restoration was complete.

Second, Floodplain Reconnection Design was discussed, a method to achieve maximum floodplain connectivity. Nash Run, a first-order tributary of the Anacostia River, was restored using the floodplain connection restoration technique as stormwater runoff led to severe bed and bank erosion, contributing to diminished water quality and degradation of instream habitat conditions. DOEE used a legacy-sediment-removal stream design technique to reduce bank erosion by creating a low and wide floodplain bench along the stream corridor. Since the completion of the restoration project, the fish populations quantities and diversity have continued to increase and the aquatic community index of biological integrity for fish is now in the ‘fair’ range and is showing steady improvements each year since restoration. As a result, Nash Run water quality improved and is closer to attaining water quality standards.

Finally, a regenerative stream approach was discussed by focusing on an effort at Alger Park in Southeast Washington DC. Prior to the restoration, Alger Park was in a highly degraded state with little to no base flow, vertical stream banks over 20 feet tall, and few areas for in-stream habitat. The stream restoration project reduced stream bank erosion to restore the incised channel. Since completion, 100,000 pounds of sediment has been prevented from being lost each year due from bank erosion and has provided valuable wetland, in-stream, and riparian habitat for native terrestrial and aquatic life.

DOEE's key takeaway is that setting clear project goals, selecting highly qualified contractors, understanding your site's potential & constraints, and choosing the right restoration techniques are all co-equal factors in achieving the project success.

Suburban – Chris Ruck (Fairfax County), Presentation Slides

Chris Ruck (Fairfax County) presented results from a suburban case study of the Flatlick Branch stream restoration located in western Fairfax County, Virginia. The watershed drains approximately 4.2 square miles with 28.6% impervious surface area and is situated in the

Triassic Lowlands, (a Level IV Ecoregion within the Northern Piedmont). Fairfax County identified this as a potential project in the late-1990s and early 2000s but did not initiate a project until 2008. After implementation of the 2010 Chesapeake Bay TMDL sediment and nutrient goals, the project was redesigned, with construction of over one mile of stream restoration completed in 2018. The Flatlick Branch project is a priority 1 stream restoration following a natural channel design approach. The stated goals of the project were: reduce nitrogen, phosphorus, and sediment transport to the Bay (for Bay TMDL credit); maintain stability of the stream restoration and its structures (for maintenance of Bay TMDL credits); maintain appropriate floodplain connectivity; and create habitat for biological improvement. In general, this was an unusual project for Fairfax County to implement due to the large size of the watershed and duration of the project.

Another unique aspect to this project was the wealth of pre- and post-monitoring data available at this location due to a USGS gage and associated programmatic monitoring at the downstream end of the restoration. This comprehensive monitoring program was implemented 10 years prior to the restoration for the express purpose of monitoring changes to the watershed during the implementation of stormwater improvement projects. A combination of continuous monitoring along with monthly, annual, and storm event samples were used to determine sediment/nutrient loads as well as local hydraulics, the physiochemical condition of water, and biological assemblages.

The monitored outcomes of goals indicate statistically significant reductions in flow-adjusted loads of suspended sediment, total nitrogen, and total phosphorus after project implementation. The post-restoration reduction in sediment and phosphorus exceeded the credited reductions for these parameters by over double the credited amount. However, the reduction in nitrogen was only marginally greater than the credited load. All three parameters indicate better efficiency from the stream restoration project than what was credited. The project also achieved its stated goals of stability, floodplain connectivity, and habitat creation. Goals related to physiochemical and biological conditions outcomes were not stated as part of the project but were measured. In general, the post-stream restoration condition indicated statistically significant increases in mean stream temperature, daily flux of dissolved oxygen (a proxy for stream metabolism), and an increase in the stream pH. The fish assemblage changed after restoration, losing minnow species, and increasing the relative abundance of warm water sunfishes. Monitoring of a nearby tributary indicated the restoration influenced the tributary’s fish assemblage as well. Finally, the benthic macroinvertebrate community, as measured by the Fairfax County Index of Biotic Integrity (IBI), showed marginal increases in the mean IBI. However, the highest annual IBIs were in the years immediately preceding the restoration so no statement could be made as to the improvement (or lack thereof) of the benthic community as a result of the stream restoration project.

This case study indicated that management practices focusing on few impairments, sources, or stressors will likely limit holistic restoration outcomes in multi-stressor watersheds. Further, both regulatory and non-regulatory drivers of stream restoration impact the restoration goals, design, and outcomes. Modifying stream ecosystems based upon project drivers will require trade-offs that may limit recovery or delay functional uplift. In complex urban and suburban watersheds, it is unclear what level of ecosystem recovery is possible. Therefore, robust monitoring particularly to evaluate goals, expected outcomes, and probable confounding sources of stress should be a requirement. Concluding remarks and subsequent discussions related to this presentation indicated great success in achieving the stated goals. It was hypothesized that the negative water quality changes post-restoration were likely due to a trophic cascade from canopy removal allowing for algal growth. Additional comments indicated that creating more slow-moving, warm, deep-water habitat would affect the fish assemblage.

Restoration Outcomes and Ecological Uplift (Panel)

Sadie Drescher (Chesapeake Bay Trust) facilitated a panel of synthesis presentations on restoration outcomes and uplift. Talks evaluated the literature of monitored outcomes from past stream restoration projects and considered whether ecological uplift occurred and what was not achieved in the restoration project. Speakers cited which goals and practices were assessed and monitored, the restoration outcomes in the stream corridor (including unintended outcomes), whether the stream restoration was undertaken to improve the Bay, and if stream stressors were mitigated by the presented stream restoration.

In-channel biotic responses – Mark Southerland (TetraTech), Presentation Slides

The history of biological response to stream restoration includes notable successes but also many instances of little or no improvement in the resident biological communities. Overall, Southerland stated that the few studies that have occurred, have shown that significant biological uplift in the channel from stream restorations in the Chesapeake Bay watershed is rare. In a single study, following stream restoration, both fish and benthic macroinvertebrate communities resembled non-restored streams, rather than high-quality streams or stream-wetland complexes. Examples of biological uplift include frogs in stream-wetland complexes, benthic macroinvertebrates where riparian areas have been improved, fish where blockages have been removed, and hyporheic taxa.

The factors limiting biological uplift are many and often elusive, given that monitoring is also rare or often inadequately designed. Only a small proportion of projects are monitored, and most are only monitored after construction - thus necessitating the utilization of reference sites that may be less degraded than the project site, have differing history than the site, and/or create variability that masks the signal. Instream habitat may be improved without biological uplift because water quality (e.g., temperature, dissolved oxygen, conductivity) remains limiting. Some studies suggest that abundance or diversity may increase only after 8 years post-restoration. Barriers to movement and proximity to source populations have also been shown to significantly affect biological uplift.

Biological outcomes may improve if restorations target sites with single or few stressors that can be remediated. Ultimately, watershed condition (including past land uses) determines biotic uplift potential and should set the expectations for stream restorations. Therefore, the guidelines for intervention could include (1) avoiding sensitive species and communities, (2) using least invasive approaches first, (3) filling gaps in good landscapes, (4) removing physical barriers, (5) adding missing or diverse habitats, and (6) giving restorations time to mature.

Stabilization responses – Tess Thompson (Virginia Tech), Presentation Slides

Streams are complex geomorphic systems impacted by regional climate, tectonics, and base level, as well as watershed geology, topography, soils, and vegetation. Historic and current human activities also play a significant role in channel form. As a result, stream restoration efforts should always be viewed within the context of place. In considering research related to the ability of stream restoration projects to restore geomorphic stability to stream systems in the Chesapeake Bay watershed, Tess Thompson presented on projects that had occurred in humid temperate climates with limited tectonic activity. The studies were limited to projects completed on 1st to 3rd order, sand-bed, and gravel-bed alluvial channels.

Given the time required to design, permit, construct, monitor, and report on stream restoration projects, the majority of peer-reviewed research extant at the time of the workshop focused on projects designed as channels in the “sediment transfer zone” (Schumm 1977) where “… a stable river, from a geomorphic perspective, is one that has adjusted its width, depth, and slope such that there is no significant aggradation or degradation of the stream bed or significant planform changes (e.g. meandering to braided) within the engineering time frame (generally less than about 50 years)” (Biedenharn et al. 1997).

Projects that have been formally evaluated for channel stability have typically been designed using a technique known as “natural channel design” (NCD) where the restoration designer chooses the channel width, depth, and slope and then holds that stream geometry using structures, typically constructed of large rock. Research from three of four different studies shows that, overall, NCD projects can successfully stabilize channel form. For example, Buchanan et al. (2014) evaluated a project along Mill Creek, a 3rd order channel near Slaterville Springs, NY. The researchers stated that the goal of the stone structures was to maintain the channel planform during vegetation establishment. Initially, the project experienced extensive aggradation and avulsion due to a large storm event. Following corrective actions and growth of riparian vegetation, the channel remained stable four years after the initial disturbance.

In a second study, Doll et al. (2015) assessed 156 streams throughout the state of North Carolina (93 restored by Natural Channel Design, 21 impaired, 29 reference and 13 reference with some incision) using the Stream Performance Assessment (SPA) rapid assessment methodology. Principal component analysis (PCA) showed that the restored streams aligned closely with reference reaches in terms of geomorphic condition, and even exhibited a greater variability in bedform and habitat condition. The authors stated that these results support the adequacy of stable stream design and construction by practitioners.

Thompson and Smith (2021) conducted a rapid visual assessment of 65 stream restoration projects in Maryland, ranging in age from 3 to 26 years. The majority of the projects had been designed using NCD. Study results showed geomorphic function was positively correlated to channel width:depth ratios, and negatively correlated to large bed particle sizes relative to bankfull depth and decreases in agricultural landuse over the period 2001 to 2016. The authors concluded that stream restoration projects are more likely to be stable if they are located in rural watersheds or watersheds with stable land cover. Additionally, projects where there are no constraints to reducing bank height to increase floodplain access were more stable.

A fourth study documented ongoing channel adjustment six years following restoration project completion. Bain et al. (2014) monitored Nine Mile Run in Pittsburgh, PA following a large stream restoration project that included the removal of mine leachate and fish passage barriers, as well as sewer upgrades. The authors found that an average of 44 cm of sediment eroded from the reach post-construction, despite the presence of armoring by rock with diameters in excess of 20 cm. While there was "continual and substantial" improvement in the fish community post-restoration, and evidence of a healthier, more diverse benthic macroinvertebrate fauna, the authors noted ongoing channel geomorphic adjustment.

A concern with NCD is that if designers incorrectly select the channel dimensions, it may be decades before the channel can readjust, given typical channel adjustment timescales (Knighton 1998). This concern is particularly acute in urban watersheds, since there is a lack of stable urban reference streams and limited room for channel adjustment (Herrington and Horndeski 2022). Additionally, the dense riparian vegetation characteristic of streams in the Chesapeake Bay watershed may prevent channels from fully adjusting to disturbance and may leave these channels in a state of "arrested degradation" (Cluer and Thorne 2014).

This review by Thompson noted that long periods of time (on the order of a decade or more) are required to determine if stream restoration actions ultimately restore geomorphic stability to streams. Given the natural variability of rainfall, many years must pass before projects are tested by a range of flood events. Additionally, decades are required for trees to mature and shade out herbaceous vegetation. It is well documented that for small streams (watershed areas roughly less than 100 km^2), channels bordered by herbaceous vegetation are narrower than similar streams with forested banks (Hession et al., 2003; Anderson et al., 2004; Sweeney et al., 2004). Therefore, as time since construction increases and the forest canopy closes, it is anticipated that restored channels will naturally widen, simply due to the maturation of the riparian vegetation.

It should be noted that, while the existing research literature is dominated by NCD projects, new design techniques, such as valley restoration, are being completed and should be the focus of future research evaluations.

Water quality responses – Paul Mayer (EPA), Presentation Slides

Stream restoration is a popular but expensive approach for managing nutrients (nitrogen and phosphorus) and sediment dynamics in urban watersheds. However, questions about costs and benefits remain. In this presentation, Paul Mayer discussed lessons learned over 20 years of investigating effects of geomorphic stream restoration on riparian and in-stream nitrogen transport and transformation in urban streams in the Chesapeake Bay watershed. He examined relationships between hydrology, chemistry, and biology to determine how flashiness, and nutrient concentrations and flux, changed after restoration. The presented data was from multiple sites (Minebank Run, Spring Branch, Dead Run, Glyndon, and Big Spring Run), and various restoration approaches including natural channel design, regenerative stormwater conveyance, and removal of legacy sediments. The data shows that restoration can be an effective nutrient management approach dependent upon re-establishing groundwater-surface water interaction (Mayer et al. 2010), addressing erosion and shear stress (Doheny et al. 2012), protecting riparian zones (Mayer et al. 2007), and ensuring sufficient cycling of organic matter for microbial activity Groffman et al. 2005). Benefits observed include: 1) reduced concentration and loads of nitrogen; 2) reduced peak flows, flashiness, and shear stress; and 3) increased denitrification (Kaushal et al. 2008). Overall, restoration effects are mixed but there are measurable improvements that make restoration a best management practice worth considering for attenuating nutrient pollution and sediment control.

There are also potential unintended consequences and tradeoffs of restoration that should also be considered, including: 1) mobilization of metals and ions after tree removal (Wood et al 2021), 2) erosion and channel degradation from poor channel design and underestimation of peak flows (Mayer et al. 2022), and 3) low dissolved oxygen from reduced flows (Duan et al. 2019). For example, restoration can reduce the stream velocity and shear stress, thereby reducing erosion and sediment transport. However, reducing stream flow can create stagnant water with low dissolved oxygen content that may affect biodiversity or increase the precipitation and mobilization of metals such as iron or manganese. Restoration can increase groundwater retention and promote reducing conditions that are favorable for denitrification (Kaushal et al. 2008). However, such redox conditions may exacerbate phosphorus mobilization (Duan et al. 2019) or flood the root zone of riparian trees. Additionally, the effects of restoration may not be realized for years after project completion because systems take time to reach equilibrium states and riparian vegetation, especially trees, require time to grow to a point where significant carbon is added to the system and where root zones establish that can stabilize banks (Forshay et al. 2022). Furthermore, channels naturally move, creating difficulty in establishing metrics for measuring success based on geomorphic dynamics.

Restorations occasionally may degrade to a pre-restoration state due to extreme weather events and high storm runoff episodes that erode the key features that contribute to sustainable groundwater quality (Mayer et al. 2022). Better monitoring of restoration projects is needed, and standardization of methods would allow for cross comparisons. Employing before, after-control impact (BACI) designs, synoptic monitoring, and multiple metrics including biological endpoints and chemical mixtures (i.e. chemical cocktails; *sensu* Kaushal et al. 2022) would better illustrate the benefits and trade-offs of stream restoration. Design-specific monitoring would also reveal outcomes of specific restoration approaches. Finally, restoration cannot necessarily deliver all benefits desired by resource managers. That is, it may not be reasonable to expect restoration to protect infrastructure, reduce nutrients, control sediment control, and provide biological uplift simultaneously. Furthermore, the benefits of restoration are not complete. For example, while restored streams can improve nitrogen uptake and attenuation, the maximum improvement observed across published studies is about 30% over unrestored stream reaches (Newcomer-Johnson et al. 2016). Therefore, restoration is limited in what it can achieve and other forms of management and/or source control are needed to holistically manage risks to water quality (Pennino et al. 2016).

Riparian responses – Lisa Fraley-McNeal (Center for Watershed Protection) & Meghan Fellows (DE Center for Inland Bays), Presentation Slides

Lisa Fraley-McNeal (Center for Watershed Protection) and Meghan Fellow (DE Center for Inland Bays) jointly presented on riparian responses to restoration and uplift. Fraley-McNeal discussed the "Maintaining Forests in Stream Corridor Restoration and Sharing Lessons Learned" 2022 collaborative report, and Fellows presented on establishing and maintaining riparian quality "in a TMDL world" while avoiding unintended consequences.

Maintaining Forests in Stream Corridor Restoration and Sharing Lessons Learned

– Lisa Fraley-McNeal *(Center for Watershed Protection)*

The importance of forest buffers for stream health has been widely documented (Belt et al., 2014). With growing interest and implementation of stream restoration in the Chesapeake Bay watershed, there is an increasing need for research about how to protect riparian buffers and minimize impact on those buffers, especially healthy, mature trees, during stream restoration construction. The Chesapeake Bay Program Stream Restoration Expert Panel Report (Schueler and Stack 2014) and recent work group updates (Wood et al. 2021) intended for the stream restoration crediting protocols to be part of a holistic watershed approach and included qualifying conditions that offer some protection for riparian vegetation. However, stream restoration projects are commonly implemented with the main goal of obtaining TMDL credits and the qualifying conditions for riparian vegetation have not been consistently met.

The Center for Watershed Protection, Inc. (CWP) worked collaboratively with the CBP and stakeholders to evaluate methods to reduce impacts of stream restoration projects on existing riparian ecology and forest buffers in Maryland, Pennsylvania, and Virginia (CWP 2022a). Findings from the project were used to develop a guidance document (CWP 2022b) for local governments on the best practices to minimize unintended adverse outcomes to riparian forests/ecosystems and identify opportunities for coupling these practices to improve water quality and habitat improvements.

Loss of existing trees in the riparian zone from stream restoration implementation typically can occur either through direct removal during construction or mortality afterwards due to increased groundwater elevations and/or extended inundation of the floodplain, compaction, and root disturbance from construction activities. Years of ecosystem maturation may be needed before a project fully meets its long-term restoration objectives and realizes its full environmental benefits (Kaushal et al. 2021, Wood et al. 2021). Projects that involve extensive channel reconfiguration or remove existing riparian cover are likely to see less functional uplift, including nutrient removal, at least until the replanted areas achieve maturity (Orzetti et al. 2010). The loss of riparian cover, as well as decreased streamflow, and widened channels are also drivers of rising in-stream water temperatures that need to be considered in conjunction with the role of microtopography and groundwater interactions (Batiuk et al. 2023). This loss of trees has resulted in public criticism of stream restoration projects.

Stream restoration project sites are generally selected through a combination of opportunistic considerations, watershed assessments conducted as part of a watershed planning initiative, and mitigation banking efforts. However, funding availability and landowner willingness are typically the ultimate drivers of site selection. Proper site selection using a watershed-based approach was identified as the most important best practice to target projects to areas in need of restoration and prevent impacts to existing high-quality streams and riparian areas. To achieve this, there is a need for clear definitions of existing “high” and “low-quality” streams and riparian areas that need restoration, and guidance from state regulatory agencies.

During the design and permitting process, the removal of entire forest buffers or mature trees is largely a value decision made by the municipality or other authorizing entities. While forest agencies are involved in stream restoration projects, the types of agencies and their current level of involvement is highly variable among jurisdictions. In addition, there are some regulations such as the Federal Emergency Management Agency (FEMA) No-rise Certification in Virginia that have become drivers of riparian tree loss. The No-rise Certification has resulted in stream restoration projects on larger streams designed following Natural Channel Design Priority 2 that creates a new channel and lowers the floodplain to avoid requesting a Conditional Letter of Map Revision (CLOMR) or variance to the requirements, resulting in a greater clearing footprint and hardened or armored restoration to provide stability. Important best practices for design and permitting include pre-application meetings with federal and state permitting agencies and coordination with forest agencies. Proposed stream restoration projects should be developed through a functional assessment process, such as the Stream Functions Pyramid, in order to optimize the restoration approach. The Stream Functions Pyramid, a guide for assessing and restoring stream functions, is a five-level hierarchical framework that categorizes stream functions and parameters that describe those functions. More information can be seen in a presentation by Stream Mechanics about improving stream restoration and mitigation relevant to Section 404 of the Clean Water Act, here (Will Harman, Stream Mechanics, Inc.).

Post-construction stream restoration monitoring is typically focused on stream stability and not riparian ecosystems. Most restoration projects undergo monitoring for 2 to 5 years after construction, based on required state and federal permit conditions. CBP stream restoration verification for crediting is also required using visual inspections once every 5 years. Funding is the primary limiting factor for extensive post-construction monitoring, particularly for grant-funded projects. To help with funding limitations related to monitoring, a pooled monitoring approach is recommended and for local governments and funding agencies to allow for a percentage of funds to be allocated for post-construction monitoring and maintenance and extend the allowable project period so that monitoring can occur over the long-term to address the restoration questions posed at the onset of the project.

Riparian Quality: Why trees matter in achieving desired restoration outcomes

– Meghan Noe Fellows (Delaware Center for Inland Bays)

Stream restoration outcomes are driven by best practices in site selection, design, and monitoring and management; this is true of not just the stream channel but also the riparian community adjacent to the stream channel. Although regulations for water quality do not set riparian metrics, research at Fairfax County, Virginia’s stream restoration projects indicate that good design, implementation, and monitoring and maintenance can lead to better outcomes: (1) detectable changes in riparian condition following restoration, (2) ecosystem changes due to restoration are under the influence of deliberate design for riparian condition improvement, (3) and riparian responses are not always for the worse.

During site selection, riparian vegetation communities are often too quickly assessed, and/or assumptions of quality are too narrowly focused to effectively understand the nuances of vegetation condition. For instance, the Wetland Indicator metric, one of the tools to determine if a riparian community is composed of wetland species, changes whether you include non-native invasive species (habitat generalists). Non-native invasive plants can have obvious and subtle effects on the function of the riparian system; removing them from the stream corridor will elevate riparian quality. Finally, it is not safe to assume that one metric, in-channel stream health, can measure the health of the whole stream corridor. In a study of total carbon in floodplain soils adjacent to the stream channel, total carbon was much higher 10 years post restoration than those in the best available, unrestored streams (Napora et al. 2023).

Carefully selecting a degraded site for a restoration project, by including metrics of riparian condition, can lead to choosing best management practices that remove stressors from the stream corridor. Non-native invasive plant management, removal of conflicting land uses, and planting are some of the more common techniques. In Fairfax County, although sites selected for restoration showed poorer riparian Floristic Quality Index than best available sites for the County (p=0.089); post-restoration vegetation did not show the same difference (e.g., restored streams were similar to the best available streams; p=0.91) (Figure 9). Theoretically, one could plant to improve floristic quality immediately following restoration. However, the plants thriving on the site after 10 years may bear little resemblance to the initial plant palette due to having been through multiple establishment filters (processes that lead to differential mortality and survival among species) and are more likely to reflect a true ecological lift.

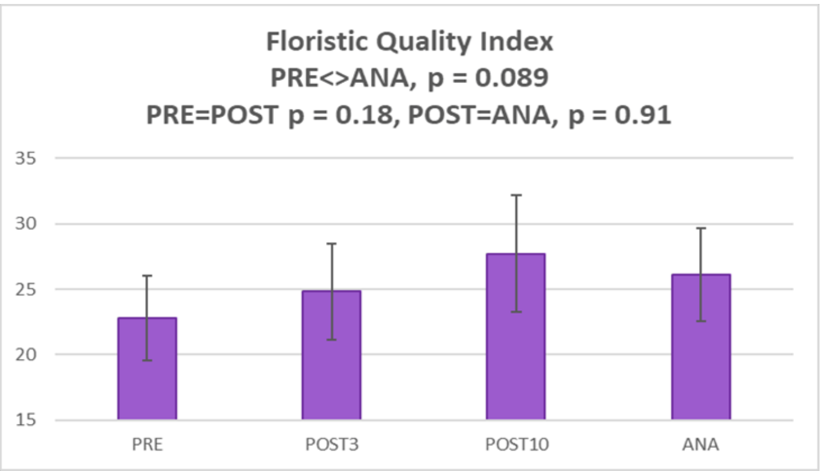


Figure 9. Floristic Quality Index before (PRE), and after restoration (3 years after-POST: 3, 10 years after-POST: 10), and best available site conditions (ANA) suggests restored streams generally have greater riparian floristic quality compared to before restoration or to high quality reference streams.

Tree loss during stream restoration continues to plague the practice of stream restoration. Although best practices minimize tree loss and plant native trees and shrubs, the loss of some older trees and the associated tree canopy cover is unavoidable in urban forested streams. Loss of tree canopy cover can exacerbate the lag in stream quality/function following restoration (e.g., stream temperatures can rise when there is less shade after restoration). One technique that shows promise in returning the tree canopy, quickly, is applied nucleation (planting trees/shrubs in a deliberately placed dense cluster vs. evenly distributed across the site). Deliberately and carefully planting woody diversity during restoration can result in tree conditions similar to pre-restoration condition (p=0.691) (Figure 10). Ecological resiliency in the riparian corridor adjacent to the stream may need techniques like applied nucleation to bridge the gap between pre- or post-restoration and best available reference conditions (p=0.003, p=0.004 respectively).

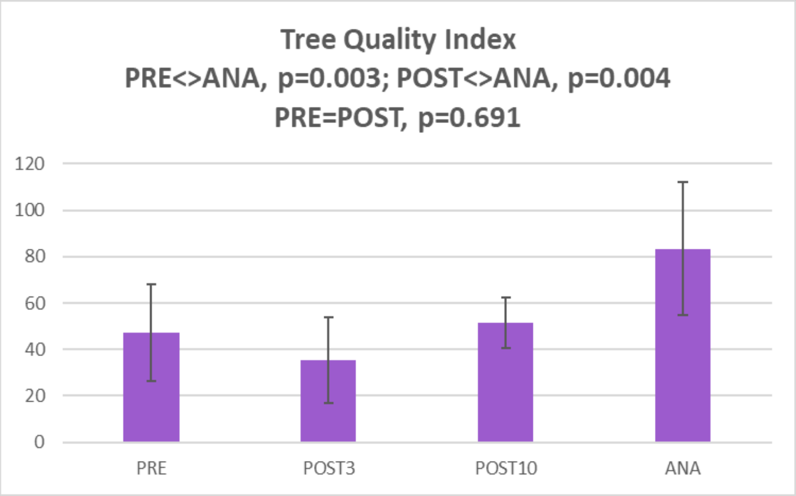


Figure 10. Tree Quality Index, a calculated metric, shows that streams selected for restoration (pre-restoration; PRE) often have a lower quality than best available reference streams (ANA). Post restoration, particularly at 10 years (POST10), shows no loss of tree quality from the PRE condition.

Understanding stream quality requires a holistic suite of conditions, not just one metric, that includes both the stream channel and the adjacent riparian system. This holistic view can direct restoration to deliberate planning, implementation and maintenance which can achieve ecological lift. Careful site selection to avoid the systems that cannot achieve lift and to restore those that can, implementation practices that work to improve the whole corridor, minimizing the stressors to ecological functioning, and careful monitoring to know that the process is having the desired effect will contribute to achieving ecological lift and minimizing undesirable outcomes.

Synthesis of the Best Available Science, Practices and Monitoring to Enable Adaptive Management

Session 3 Objective: How do we advance stream restoration to improve restoration outcomes (including ecological uplift)?

The final workshop session was comprised primarily of small breakout discussions, organized with the primary goal of considering how to achieve better outcomes. Summaries of the breakout group conversations are included in the following section. Session 3 included one formal presentation, a closing plenary given by Erik Michelsen (Anne Arundel County).

The Future of Environmental Recovery is Dependent on a Paradigm Shift that Embraces the Past (Closing Plenary) – *Erik Michelsen* (Anne Arundel County), Presentation Slides

Erik Michelsen, Senior Environmental Policy Officer with Anne Arundel County Department of Public Works, gave the closing workshop plenary in which he emphasized the importance of understanding historical context in addressing current environmental challenges. In the presentation, Michelsen spoke about a fundamental change in stream restoration that seeks to allow past experiences to shape expectations for the future. Walking through the evolution of restoration practices, from traditional engineering approaches to more holistic and ecological designs, Michelsen advocated for alternative practices that prioritize biological and ecological outcomes.

Quoting a talk given by workshop steering committee member Ben Hayes (Bucknell) the day prior, Michelsen notes that “memory shapes our future” and like so many other endeavors focused on the natural world, the stream restoration effort suffers from a widespread case of ecological amnesia, aiming its recovery target at badly impaired "references" rather than aiming for the pre-impairment functions of these systems prior to their impairment. This enables each generation to perceive the current state as the norm regardless of environmental impairment.

Over the past 20 years, a sub-group of practitioners, increasingly informed by the evolving science in stream restoration, have been working to design and build corridor systems that emulate these pre-impairment functions, often without knowledge of each other's work. Examples of convergent and evolving approaches are Regenerative Stream Conveyance (RSC), legacy sediment removal, valley restoration, beaver dam analogs, and Stage Zero restoration. Sites exhibited altered plant communities following colonization, with precolonial conditions characterized by wooded scrub, shrubs, and forested swamps of Alder, Oak, Hickory, and Fern. Postcolonial conditions include canopy losses, reduced hardwoods, increased herbs, cattail, grasses, and upland pine.

Contemporary scientific analysis examining these novel projects corroborates their effectiveness at reducing nutrients and sediment downstream, as well as attenuating flooding and maintaining stability in the face of increasingly intense weather. Michelsen closed by emphasizing that within the field of stream restoration, it is time for the reference paradigm for this work to shift in order to optimize ecological recovery.

Breakout Discussion Summaries

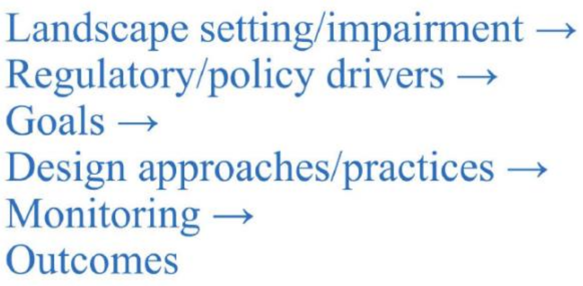
Participants were randomly split into small groups to consider various outcomes of stream restoration. Breakout discussions occurred in both Session 2 and Session 3, first focusing on which practices lead to certain outcomes, and later, on what can be done differently to achieve better outcomes. Virtual attendees were divided into remote breakout groups and encouraged to document their responses using digital collaboration platforms. A complete list of participant responses can be found in Appendix B.

Why are we getting these outcomes? (Day 2 Breakout Session)

The steering committee posed the following questions for participants to contemplate in the first breakout as part of Session 2, which concentrated on current stream restoration impacts and outcomes:

1. How have historical and present conditions been incorporated into restoration goals and approaches?
2. What regulatory/policy drivers led to different goals and approaches?
3. What are the stressors that led to stream impairment and to what degree have stream restoration approaches addressed them?
4. Has the monitoring of outcomes been effective and sufficient, including biotic uplift?
5. When outcomes have been successful, why were they successful? What has worked?

The steering committee also suggested that the 'rubric' of the proposed causal chain of stream restoration be considered by the breakout groups (Figure 11).



Landscape setting/impairment →
Regulatory/policy drivers →
Goals →
Design approaches/practices →
Monitoring →
Outcomes

Figure 11.Causal chain of stream restoration approaches. Slide provided by Greg Noe (USGS).

An overall summary for each question is provided below, as well as individual summaries by breakout group. Summaries by breakout group can be found in Appendix C, including images of notetaking documents if available.

Overall Summary by Breakout Question:

How have historical and present conditions been incorporated into restoration goals and approaches?

- Taking historical impairments/impacts and present conditions into consideration when proposing restoration projects can help set relevant and achievable goals as well as restoration approaches, but not all projects or resource management goals adopt this process.
- There is considerable variability among projects regarding the incorporation of historical and present conditions, but TMDL-driven projects need to take a more holistic approach to understand watershed changes and pollutant sources.
- One of the reasons that historical and present conditions have not been generally considered is that practitioners and managers had their preferences towards certain restoration approaches (e.g. Natural Channel Design), although in the recent past restoration approaches have diversified.
- Projects are sometimes limited by constraints such as sewer lines, road crossing, buildings, and avoidance of creating fish blockages.
- It is difficult to know biological conditions without long-term data from the period before restoration.

What regulatory/policy drivers led to different goals and approaches?

- Drivers vary across states. Bay TMDL is a main driver in VA and many other locations. Other drivers in VA and elsewhere include:
    - Infrastructure protection (e.g., Minebank Run).
    - A number of stream mitigation types.
- Checks and balances required.
- Level of vegetation protection requirements.
- Level of follow up information required for TMDL and MS4 projects versus mitigation projects.
- Credits equivalent to reducing impervious surface.
- Functional credits, but to a lesser degree.
- In summary, goals and approaches tend to follow the money/funds.

What are the stressors that led to stream impairment and to what degree have stream restoration approaches addressed them?

- Land use change and urbanization are major stressors but, in general, stream restoration approaches do not address them. Many restoration projects are too small to meaningfully contribute to addressing these stressors, and the level of impairment

from these stressors can limit a stream's restoration potential. There is excessive concern about geomorphic stability goals, which leads to overdesigning restorations to be unchanging without addressing sources of impairment. One problem is that no erosion can be present in stream bank for credits to be granted.
- It isn't always clear what is the stressor or stressors that are directly impairing a reach targeted for management, making the choice of stream restoration approach, or other watershed management action, unclear and often ineffective.

Has the monitoring of outcomes been effective and sufficient, including biotic uplift?
- No. A lot of monitoring has been focused on structural aspects of stream channel, with insufficient monitoring of ecological and biological responses.
- Level of monitoring depends on the driver of restoration. For instance, there is more monitoring for mitigation projects than for others.
- In general, more projects need long-term monitoring to assess outcomes of projects and thus to enable adaptive management of stream restoration.
- Data sharing needs to improve.

When outcomes have been successful, why were they successful? What has worked?
- Success is often linked to having clear restoration goals, sufficient funding, and sufficient monitoring to assess those goals.
- Better biological outcomes are more likely to occur where the stream restoration addresses a single important stressor, such as acid mine drainage, stream burial, or fish blockage, and in smaller watersheds.
- Restoring the ecosystem across the whole width of the stream valley, including the floodplain and riparian zones.
- There was some disagreement in the group about monitoring outcomes. Some said that not enough pre- and post- monitoring data are available to know what worked, what improved, and what didn't. Others disagreed saying that the updated stream restoration calculator, the updated restoration protocol, and new methodologies used to evaluate credits are improvements.
- Monitoring has been very nutrient and sediment credit-driven, not accounting for other functions. There should be incentives for monitoring the recovery of other ecological functions.
- Goals have not always been clear, making it difficult to assess outcomes.

How do we advance stream restoration to improve restoration outcomes including ecological uplift? (Day 3 Breakout Session)

The steering committee posed the following questions for participants to contemplate in the first breakout as part of Session 3, which concentrated on creating a synthesis of the best available science, practices, and monitoring to enable adaptive management.

An overall summary is provided below. A complete list of breakout responses can be found in Appendix C, including images of small group notetaking documents (i.e., Jamboard).

Overall Summary by Breakout Question:
What can we do differently to get better outcomes?

- Stream restoration is currently often the most cost-effective BMP (annual, life cycle cost) to meet the Bay TMDL, which drives funding, design, and implementation often to the detriment of ecological goals and outcomes. A lack of science and understanding on how to achieve ecological uplift keeps static, low-maintenance, hardened channels as the preferred alternative for design approaches to meet regulatory requirements.
- Identify stressors so that restoration approaches can be chosen that address those stressors.
- Develop clear and realistic goals, and if the goal includes ecological uplift, then explicitly state that goal and choose appropriate restoration approaches. Communicate those goals to the public.
- Take an ecosystem approach with multiple metrics to evaluate outcomes.
- Incorporate the stream valley's riverscape corridor into restoration, which includes the riparian zone and floodplain.
- Obtain monitoring/assessment data prior to and after restoration.
- Regularly develop reviews of the science.
- In urban streams, infrastructure limitations impact design approaches, and high and increasing impervious cover makes in-channel biotic uplift challenging, but some settings and approaches are more likely to succeed (such as daylighting streams).
- Geomorphic channel stability may or may not lead to ecological uplift. Design approaches to stream restoration that incorporate dynamic geomorphic changes and evolution over time may help ecological uplift, but more science is needed to identify the consequences that geomorphic hardening and stationary conditions have on stream biology.
- Monitoring of stream restoration outcomes is often insufficient to either evaluate success relative to the stated goals or to enable adaptive management that could identify improved approaches. Robust monitoring programs that assess project goals and scientific needs using sound approaches would help adaptive management. Monitoring also should focus on multiple metrics of stream ecosystem health. The time scale needed for proper assessment of stream restoration outcomes may be as long as 10-20 years. Robust evaluation of both successful and unsuccessful projects will advance the practice of stream restoration.
- Conflicting regulations, variability in the required outcomes, and numerous authorities for stream restoration oversight inhibit the flexibility to use novel, or dynamic design approaches. Further, performance standards set by review agencies are largely inflexible and differ throughout the Bay watershed. Development of performance standards that allow for changing/dynamic stream systems that meet regulatory and agency requirements would enable the testing and identification of stream approaches that work better.

- The term “stream restoration” can mean many different things and has often been assigned to many different restoration approaches. Clearer terminology, that includes the goals of the project, could help with articulating project goals to the public. See Appendix D for a possible approach for refining the definitions and naming of stream restorations.

Summary of Recommendations and High Priority Science Gaps

Why Was This Workshop Held?

Implementation of stream restorations has grown rapidly in Chesapeake watersheds, primarily driven by requirements to reduce nitrogen, phosphorus, and sediment (N/P/sed) loads to downstream waters including the Chesapeake Bay. Motivation for restoring streams extends beyond load reductions and can include functional uplift to improve the status of aquatic biota and riparian corridor habitat as well as geomorphic stabilization to protect infrastructure. The rapid increase in stream restoration implementation throughout the Chesapeake Bay watershed over the past two decades has led to growing concern and controversy about the effects of stream restoration on whole-ecosystem health and services. Over time a growing, but limited, number of studies have documented the results of stream restoration practices, allowing the opportunity to summarize these findings and to provide insights and recommendations to improve implementation. We convened a diverse group of experts in stream restoration implementation and science that included practitioners, managers, and researchers from industry, government, and academia. We focused on describing the 'causal chain' of how stream degradation has led to policy and regulations, that then determine the goals of restoration projects, that then influences implementation practices and how they are monitored and assessed, and that then leads to documented restoration outcomes.

For this workshop, we followed the Society for Ecological Restoration's definition of restoration as "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed." (Gann et al. 2019).

Key Workshop Summary

Most often stream restoration projects may not have the primary goal to improve ecological uplift and therefore often do not improve aquatic macroinvertebrate or fish communities.

In the Chesapeake watershed, stream restoration has often occurred in response to Clean Water Act mandates to reduce nitrogen, phosphorus, and sediment loads to the Bay. This motivation for stream restoration then influences the goals and approaches of individual restoration projects. Restoration outcomes summarized at the workshop identified often minimal improvement to stream aquatic biota, effective 'stabilization' of channel form over time, moderate improvements to water quality, and short-term negative impacts to riparian vegetation. Stream restorations that reduce erosion, sediment, and nutrients can be beneficial to those streams as well as downstream waters. Continued and improved assessments of the outcomes of stream restoration are essential to understand the effectiveness of management efforts and support adaptive management.

In general, the workshop summarized the factors that have led to differing outcomes from stream restoration. This "causal chain" is a synthesis of stream restoration in the Chesapeake Bay watershed:

Landscape setting/impairment → Regulatory/policy drivers → Goals → Design approaches/practices → Monitoring → Outcomes.

Specific recommendations, issues, and knowledge gaps for improving outcomes of stream restoration (<u>underlined text highlights the most important findings</u>):

Theme 1: Recommendations to achieve better outcomes from stream restoration

- <u>If improved ecological functions (ecological uplift) are a main goal, then explicitly identify them and make them a goal, and use appropriate restoration design approaches to achieve that goal, and monitor those restoration outcomes.</u>
    - Follow existing regulatory and policy requirements, where applicable, that functional uplift must occur.
    - Clearly state the objectives of a restoration, including identification of which ecological functions are targeted, and the objectives should be measurable and quantifiable.
    - Even if the project's primary goals do not include ecological uplift, improvements to stream biology and ecosystem functions can be a co-benefit and the restoration approach optimized to increase the likelihood of ecological uplift.

- Identify the stressors to stream ecosystem health prior to restoration so that management approaches are likely to alleviate those stressors.
    - Expectations of ecological uplift for a project may not be realistic if the restoration approach does not (or cannot) address the stressors and constraints operating on that stream reach, limiting restoration potential.
    - Target streams where there is a single or few identified stressors that can be managed through stream restoration to alleviate those stressors, or streams where those stressors are being effectively managed elsewhere in the upstream watershed.

- Consider the appropriate historical and contemporary conditions and processes that define the restoration potential of the stream in order to identify project goals, design approach, and assessment of sustainable outcomes.
    - Select a design approach that would result in stream-floodplain system processes that are self-sustaining over time, where appropriate, given existing and likely future conditions of the watershed and stream, and location of the stream in the watershed. This includes considering and choosing the desired restoration target or reference condition for the stream.
    - Assess the pre-restoration ecosystem condition of the stream reach in order to inform project goals and design approach, and to enable post-restoration evaluation of outcomes.

    - Restore the entire stream corridor including all of the components of the connected stream system (lateral, vertical, up-downstream, and temporal variation), such as the channel, hyporheic zone, riparian zone, and floodplain (Harvey and Gooseff 2015, Wohl et al. 2021)

- Focus on holistic ecosystem condition and resilience, not only geomorphic stabilization, and allow sufficient dynamic change to promote stream evolution that optimizes ecological functional uplift and dynamic habitats at a rate that does not adversely impact biological and water quality resources.

- <u>Avoid harm</u>. Target stream restoration for locations with more strongly disturbed stream reaches, use approaches that are more likely to address stream ecosystem stressors and generate improved functional uplift, and avoid harming higher quality streams and their riparian zones.
    - Target smaller streams for restoration and consider the condition of upstream reaches when restoring larger streams.
    - Use caution when using approaches that could negatively alter cold, free flowing streams or riparian zones that have existing high quality biota.
    - Target headcuts, knickpoints, headwaters, concrete channels, buried streams, and disconnected floodplain-stream systems for ecological uplift.
    - Recognize that inaction is a choice and can lead to further degradation, and restoration can set the stage for future improvement following alleviation of untreated stressors.
    - Avoid negative unintended consequences to the stream-riparian system through appropriate design for that location.

Theme 2: Policy issues that impact outcomes of stream restoration

- <u>Most stream restoration projects for the Chesapeake Bay TMDL have the primary goal of nutrient and sediment reduction to the Bay, but do not currently incentivize funding or prioritization for local stream biotic uplift.</u>

- <u>FEMA rules discourage changing (increase or decrease) flood levels, restricting the rewetting of the riparian corridor and floodplain and potentially limiting functional uplift</u>.

- Long-term monitoring of holistic ecosystem outcomes from restoration, with clear linkage to project goals and objectives, could be incentivized in order to support adaptive management.

- Current performance standards for stream restorations encourage relatively static channels, i.e., minimal erosion and aggradation observed during follow-up evaluations. For improved biotic uplift, success criteria could be allowed to evolve over time, as appropriate for project goals, to allow for dynamic stream ecosystems.

- Conflicting policies, funding availability, and funding source requirements can lead to divergence in restoration goals and objectives across jurisdictions.

Theme 3: Recommendations to improve assessments of stream restoration outcomes

- Choose metrics of stream response to restoration that evaluate the project's goals and objectives.

- Assess restoration outcomes against project goals using multiple metrics of stream ecosystem health (such as multiple taxonomic groups, ecological processes, human use and engagement, socio-economics, the riparian zone, and functional processes) and a study design to test hypotheses and assess whether project goals and objectives have been achieved.

- Additional long-term focused monitoring can help to understand and adaptively manage restoration outcomes.

- Assessment of restoration outcomes could consider the possibility of differing time lags of the response times of different stream ecosystem health metrics to project implementation.

Theme 4: High priority science gaps

- Improved scientific understanding and predictions of stressors to the stream ecosystem can provide additional information at the spatial scale of individual stream reaches that would assist choosing the most appropriate restoration approach.

- Research to quantify levels of geomorphic change associated with healthy stream ecosystems in the mid-Atlantic region.

- More science can help to identify how to improve the ecological condition of streams through management.

- The terminology of "stream restoration" could be refined to be more specific of actual management goals, objectives, and practices of each project in order to better communicate project intentions.

- Additional long-term monitoring of ecosystem responses to restoration beyond regulatory and permit requirements, including the pre-restoration period, can inform future decision making.

- Publicly available databases of stream restoration project goals, objectives, implementation information, and assessed outcomes that are comprehensive and follow data usability guidelines can provide transparency and enable adaptive management.

- Review and development of suggested best approaches and methods for assessing restoration outcomes can help to facilitate consistent, standardized, and effective evaluation techniques.

APPENDICES

Appendix A: Workshop Agenda

Chesapeake Bay Program's (CBP) Scientific
and Technical Advisory Committee (STAC)
Workshop

The State of the Science and Practice of
Stream Restoration in the Chesapeake:
Lessons Learned to Inform Better
Implementation, Assessment and Outcomes
March 21-23, 2023
Potomac Science Center | Woodbridge, VA
Workshop Webpage

The **overall purpose** of the workshop is to bring together a diverse cross-section of experts and stakeholders in the field of stream restoration to review and distill lessons learned from past stream corridor restoration projects to improve restoration outcomes. For the purposes of this workshop, stream restoration is broadly defined as an intervention to move a degraded ecosystem to a trajectory of recovery as informed by a reference condition considering local and global environmental change. The scope of the workshop includes the riparian area. A key theme is relating the current drivers of stream restoration (regulatory, policy, etc.) to identified project goals and measured outcomes.

The workshop will be **focused on three topics**:

1. Identify the evolution of stream restoration goals, regulations, practices and practice implementation;
2. Present and discuss science and assessment to document holistic impacts and outcomes; and
3. Create a synthesis of the best available science, practices and monitoring to enable adaptive management that improves stream restoration activities.

Day 1, March 21, 2023:

8:30 am **Coffee & Light Breakfast (Provided)**

9:00 am **Workshop Overview & Objectives –** Greg Noe *(USGS)* and Neely Law *(Fairfax County)*

Discuss objectives of the workshop, an overview of the sessions, desired outcomes, and how the expertise in the room can contribute to discussion and synthesis towards improving stream restoration practices.

- Introduce the general theme of the causal pathway of stream restoration outcomes: Impairment →Regulatory/policy drivers → Goals → Design approaches/practices → Monitoring → Outcomes.
- What have been the goals (and what is target reference condition)?
- How do different goals lead to different approaches (local reach vs. watershed+ecosystem restoration)?
- What approaches lead to better outcomes?
- The need for adaptive management to improve outcomes

Session 1: Identify the evolution of stream restoration goals, regulations, practices, and practice implementation (after 1972 Clean Water Act)

Session Objective: Background information. 1) how has management or mismanagement resulted in impairment of streams (watershed and stream mismanagement)? 2) What is our understanding of how stressors influence streams and our ability to appropriately identify and address stressors? 3) What were the drivers for stream restoration? 4) And in the past, what management was taken to restore streams.

9:20 am *Opening Plenary*: **Watershed History and Evolution of Stream Degradation Patterns and Restoration –** Ellen Wohl *(CSU)*
Discussion of 1) land use change and legacy sediment and contaminants, 2) definition of reference condition of streams, 3) interaction of stream hydrology, geomorphology, chemistry, and biology, and stakeholder interests, and 4) implications for stream restoration.

9:50 am ***Opening Panel with Q&A*: The Chesapeake Nontidal Watershed History and Evolution of Stream Degradation Patterns and Restoration –** facilitated by Ben Hayes *(Bucknell)*
Opening panel discussion with questions and answer portion built-in.
Panelists: Dorothy Merritts (*Franklin & Marshall College*); Karen Prestegaard (*UMd*); Andy Miller (*UMBC*); Matt Cashman (*USGS*); Kevin Smith (*Maryland Coastal Bays Program*)

10:50 am **20-minute break**

11:10 am **Outcomes from Stream Restoration in the Past (pre-2010 period of Chesapeake Bay Agreement) –** facilitated by Tess Thompson (*VT*)
An examination of past outcomes in stream restoration before the 2010 Chesapeake Bay Agreement. Includes two summary presentations on 1) Ecology and Water Quality (15 min) and 2) Stream Stabilization (15 min). 30 minutes for Q&A.

Ecology and Water Quality Speaker: Scott Stranko (*MD DNR*) and Bob Hilderbrand (*UMCES*)

- Ecology panelists: Nancy Roth (*TetraTech*), Dave Penrose (*Penrose Environmental Consulting*), Solange Filoso (*UMCES*)

Stream Stabilization Speaker: Rich Starr (*Ecosystem Planning and Restoration*)

- Stream Stabilization panelists: Scott Lowe (*McCormick Taylor*); David Wood (*CSN*); Bill Stack (*Center for Watershed Protection*)

12:10 pm **Lunch (provided)**

1:40 pm **Lessons Learned from the Past –** Ben Hayes *(Bucknell)*
Recap on morning presentations followed by a group discussion on how the past can inform stream restoration practices and lead to better outcomes.

Session 2: Present and Discuss Science and Assessment to Document Holistic Impacts and Outcomes (2010-present) – continued

Session Objective: What are we doing now? What have we seen not go so well? What has been a "success"? What are common regulatory/policy, trade-offs, and unintended consequences (looking at both obstacles and opportunities)? What is the research telling us?

2:00 pm **Introduction to Session 2 –**Neely Law *(Fairfax County)* and Greg Noe *(USGS)*
5-minute introduction to Session 2, focusing on presenting and discussing science and assessment to document holistic impacts and outcomes from 2010 to the present.

2:05 pm **Regulatory/Permitting and Policy: Parameters for showing success** – facilitated by Rich Starr (*Ecosystem Planning and Restoration*)
A series of presentations from Bay states on current regulatory and permitting processes, voluntary efforts, and how they drive stream restoration goals. Discussion of how restoration practices affected restoration outcomes and influenced 1) reach vs. downstream

improvement approach, 2) stabilizations vs. habitat vs. water quality, and 3) diverse goals from different stakeholders/drivers of management. Each presentation is 15-minutes, followed by a 15-minute Q&A.

- Maryland – Denice Clearwater *(MDE)*
- Virginia – Brock Reggi (*VA DEQ*)
- Pennsylvania –Jeff Hartranft *(PA DEP)*

3:05 pm **20-minute break**

3:25 pm **Detailed case studies of individual stream restoration projects**
– facilitated by Chris Ruck (*Fairfax County*) and Joe Berg (*Biohabitats*)
Presentation of four stream restoration case studies that review their causal chain: Landscape setting/impairment → Regulatory/policy drivers → Goals → Design approaches/practices → Monitoring → Outcomes. Each presentation is 15-minutes, followed by 20-minutes for Q&A.

Presentation(s):

- Legacy Sediment – Robert Walter (*Franklin and Marshall College*)
- Coastal plain – Joe Berg *(Biohabitats)*
- Urban – Josh Burch *(DC DOEE)*
- Suburban – Chris Ruck *(Fairfax County)*

4:45 pm **Synthesize and Overview of Day 1; Expectations for Day 2** – Greg Noe *(USGS)* and Neely Law *(Fairfax County)*

5:00 pm **Recess**

Day 2, March 22, 2023:

8:30 am **Coffee & Light Breakfast (Provided)**

Session 2: Present and Discuss Science and Assessment to Document Holistic Impacts and Outcomes (2010-present) – continued

9:10 am **Review of Day 1; Objectives for Day 2** – Neely Law *(Fairfax County)* and Greg Noe *(USGS)*

9:20 am **Restoration Outcomes and Uplift** – facilitated by Sadie Drescher *(Chesapeake Bay Trust)*
Invited speakers will synthesize research on restoration outcomes and uplift. Presentations will consider what goals and practices were assessed and monitored, restoration outcomes in the stream corridor (including unintended outcomes), if the stream restoration is being undertaken to improve the Bay, and if stream stressors were mitigated by the presented stream restoration – why did uplift happen or not? What are we not achieving?
Presentations:

- 20-minutes: in-channel biotic – Mark Southerland *(TetraTech)*
- 20-minutes: stabilization – Tess Thompson (*VT*)
- 20-minutes: water quality (including geomorphic restoration for WQ) – Paul Mayer (*EPA*)
- 20-minutes: riparian –Lisa Fraley-McNeal (*Center for Watershed Protection*) and Meghan Fellows (*DE Center for Inland Bays*)

10:40 am **20-minute break**

11:00 am **Panel with Q&A**
A 1-hour panel discussion with 15-minute for Q&A.

12:15 pm **Lunch (provided)**

1:30 pm **Breakout Discussions**
Participants will split into small groups to discuss outcomes of stream restoration. Each group will be led by steering committee members as a facilitator and a separate note-taker. Topics for each group to discuss:

Discussion Question(s): Why are we getting these outcomes?

1. How have historical and present conditions been incorporated into restoration goals and approaches?
2. What regulatory/policy drivers led to different goals and approaches?
3. What are the stressors that led to stream impairment and to what degree have stream restoration approaches addressed them?
4. Has the monitoring of outcomes been effective and sufficient, including biotic uplift?
5. When outcomes have been successful, why where they successful? What has worked?

2:30 pm **10-minute break**

2:40 pm **Breakout Group Summary: Why did we get these outcomes?**
The facilitating steering committee member in each group will report out on the discussion and outcomes from the breakout session.

3:20 pm **Group Discussion on Initial Synthesis of Outcomes: How do different practices lead to outcomes for various goals?** – *Facilitated by Steering committee member*

4:40 pm **Synthesize and Overview of Day 2; Expectations for Day 3 –** Greg Noe *(USGS)* and Neely Law *(Fairfax County)*

5:00 pm **Recess**

Day 3, March 23, 2023:

8:30 am **Coffee & Light Breakfast (Provided)**

Session 3: Create a Synthesis of the Best Available Science, Practices and Monitoring to Enable Adaptive Management (future)

Session Objective: How do we advance stream restoration to improve restoration outcomes (including ecological uplift)?

9:00 am **Review of Day 1 and 2; Objectives for Day 3** – Neely Law *(Fairfax County)*,Greg Noe *(USGS)*

9:05 am **Breakout Discussions**
Participants will meet in the same breakout group as Day 2 to discuss ways to achieve better outcomes. Each group will be led by a steering committee member as facilitator and a note-taker.

Topics for each group to discuss:

- *What do we do differently to get better outcomes?*

10:00 am **20-minute break**

10:20 am **Breakout Group Summary and Structured Group Discussion**
– led by all Steering committee members
The steering committee member in each group will report out on the discussion and outcomes from their breakout sessions, and provide initial synthesis recommendations.

11:00 am **Synthesis Results and Recommendations** – Greg Noe *(USGS)*, Neely Law *(Fairfax County)*

11:40 am **Closing plenary** – Erik Michelsen *(Anne Arundel County)*

12:00 pm **Workshop Adjourn; Lunch (Provided)**

Appendix B: Workshop Participants

First Name	Affiliation
Drew Altland	Ecotone, LLC
Katie Atkinson	Timmons Group
Diron Baker	City of Rockville Dept. of Public Works
Joseph Battiata	Virginia Department of Environmental Quality
Emily Beacham	Koontz Bryant Johnson Williams
Sarah Benton	Rural Action
Joe Berg	Biohabitats
Keith Binsted	Underwood & Associates
Kristen Saacke Blunk	Headwaters LLC
Katie Brownson	U.S. Department of Agriculture Forest Service
Claire Buchanan	Interstate Commission on the Potomac River Basin
Josh Burch	District Department of Energy & Environment
Dave Byrd	U.S. Fish and Wildlife Service
Mieko Camp	Maryland Department of the Environment
Matthew Cashman	U.S. Geological Survey
Alex Chapla	SRF Consulting Group, Inc.
Chris Clark	Prince George's County Department of the Environment
Denise Clearwater	Maryland Department of the Environment
Meg Cole	Chesapeake Research Consortium
Scott Cox	Pennsylvania Department of Environmental Protection
Sandra Davis	U.S. Fish and Wildlife Service
Jack Dinne	McCormick Taylor, Inc.
Tom Doody	U.S. Geological Survey
Sadie Drescher	Chesapeake Bay Trust
Matt Ehrhart	Stroud Water Research Center
Matt English	District Department of Energy & Environment
Rosemary Fanelli	U.S. Geological Survey
Su Fanok	The Nature Conservancy
Meghan Noe Fellows	Delaware Center for the Inland Bays
Celso Ferreira	George Mason University
Solange Filoso	University of Maryland Center for Environmental Studies
Megan Fitzgerald	U.S. Environmental Protection Agency
Lisa Fraley-McNeal	Center for Watershed Protection

Katlyn Fuentes	Chesapeake Research Consortium
Heather Gewandter	City of Rockville Dept. of Public Works
Nat Gillespie	U.S. Department of Agriculture Forest Service
David Goerman	Pennsylvania Department of Environmental Protection
Greg Golden	Maryland Department of Natural Resources
Frank Graziano	Wetland Studies and Solutions, Inc.
Sophia Grossweiler	Maryland Department of the Environment
Rebecca Hanmer	Retired - U.S. Environmental Protection Agency
Alana Hartman	Chesapeake Stormwater Network
Jeffrey Hartranft	Pennsylvania Department of Environmental Protection
Ben Hayes	Bucknell University
Niamh Hays	Pennsylvania Department of Environmental Protection
Bob Hilderbrand	University of Maryland Center for Environmental Science Appalachian Lab
Robert Hill	Virginia Department of Environmental Quality
Mark Hoffman	Chesapeake Bay Commission
Amy Hruska	Underwood and Associates, Inc.
Meredith Hudson	U.S. Environmental Protection Agency
Shreeram Inamdar	University of Delaware
John Jackson	Stroud Water Research Center
Rikke Jepsen	Interstate Commission on the Potomac River Basin
Laura Kelm	Green Vest
Ron Klauda	Friends of Hunting Creek
Charles Kozora	OTT HydroMet
Neely Law	Fairfax County and Stream Health Workgroup
Matt Ledford	Rural Action
Raymond Li	U.S. Fish and Wildlife Service
Scott Lowe	McCormick Taylor, Inc.
Alex Lucado	Ecosystem Services
Bel Martinez da Matta	Maryland Department of the Environment
Maria Izabel Martinez da Matta	Maryland Department of the Environment
Tou Matthews	Chesapeake Research Consortium
Paul Mayer	U.S. Environmental Protection Agency
Shannon McKenrick	Maryland Department of the Environment
David Merkey	Green Vest

Dorothy Merritts	Franklin & Marshall College
Matt Meyers	Fairfax County
Erik Michelsen	Anne Arundel County
Andy Miller	University of Maryland Baltimore County
Tyler Monteith	Virginia Department of Environmental Quality
Anthony Morris	Virginia Department of Environmental Quality
James Morris	Watershed Environmental LLC
Scott Morris	Virginia Department of Environmental Quality
John Mullican	Maryland Department of Natural Resources
Kip Mumaw	Ecosystem Services
Katrina Napora	U.S. Geological Survey
Kelly Neff	Maryland Department of the Environment
Denis Newbold	Stroud Water Research Center
Greg Noe	U.S. Geological Survey
Efeturi Oghenekaro	District Department of Energy & Environment
Judy Okay	J&J Okay Consulting, Inc.
Katie Ombalski	Woods and Waters Consulting, LLC
Art Parola	University of Louisville
Dave Penrose	Penrose Environmental Consulting
Scott Petrey	Wetland Studies and Solutions, Inc.
Karen Prestegaard	University of Maryland
Ashleigh Read	GHD
Brock Reggi	Virginia Department of Environmental Quality
Nancy Roth	Tetra Tech
Matthew Rowe	Maryland Department of the Environment
Chris Ruck	Fairfax County Watershed Assessment Branch
Thomas Schueler	Retired - Center for Environmental Protection
Leonard Schugam	Maryland Department of the Environment
Mark Secrist	U.S. Fish and Wildlife Service
Bob Siegfried	Resource Environmental Solutions LLC
Kevin M. Smith	Maryland Coastal Bays Program
Mark Southerland	Tetra Tech
Kyle Spendiff	Green Vest
Bill Stack	Center for Watershed Protection

Teddi Stark	Pennsylvania Department of Conservation and Natural Resources
Rich Starr	Ecological Planning and Restoration
Scott Stranko	Maryland Department of Natural Resources
Julia Sullivan	Rural Action
Aaron Sutton	Resource Environmental Solutions, LLC.
Christina Thomas	U.S. Environmental Protection Agency
Tess Thompson	Virginia Tech
Josh Tiralla	Maryland Department of the Environment
Robert Walter	Franklin and Marshall College
Sara Weglein	Maryland Department of Natural Resources
Michael Williams	University of Maryland
Sherry Witt	General Dynamics Information Technology
Ellen Wohl	Colorado State University
David Wood	Chesapeake Stormwater Network
Guido Yactayo	Maryland Department of the Environment
Emily Zollweg-Horan	NY Dept of Environmental Conservation

Appendix C: Breakout (Virtual and In-Person) Group Responses

Participants met in breakout groups on Day 2 and Day 3. Depending on participation, those groups were either in-person or virtual. Workshop steering committee members were split across the breakouts to facilitate the small group discussions. Depending on the group preference, notes were taken using a preloaded digital collaboration platform or pen and paper.

Day 2 Breakout Session Responses

The first breakout took place on Day 2. Participants were requested to consider why we are receiving these outcomes. Questions asked were the following:

1. How have historical and present conditions been incorporated into restoration goals and approaches?
2. What regulatory/policy drivers led to different goals and approaches?
3. What are the stressors that led to stream impairment and to what degree have stream restoration approaches addressed them?
4. Has the monitoring of outcomes been effective and sufficient, including biotic uplift?
5. When outcomes have been successful, why where they successful? What has worked?

How have historical and present conditions been incorporated into restoration goals and approaches?

- *Breakout Group 1*
    - Need to restore landscape and watershed to restore streams. Riparian tree canopy (existing condition) is important for restoration outcomes. Need better pre-existing condition data for aquatic biotics to assess outcomes (and avoid negative impacts), and that rapid visual assessment is not sufficient.
    - Should be mandatory. Current geomorphic condition is difficult to interpret for historic condition and changes since then. Historic habitat/geomorphic matrix along stream valley was different than now (e.g. beavers + brook trout).
    - Difficult to design geomorph-hydraulics of legacy sediment projects, including riparian.
- *Breakout Group 2*
    - Not well, because of limited data for either; Not well, in urban areas, there are sequential changes that have affected hillslopes and channels: including agricultural erosion, and adjustments to urbanization.
    - Pre-colonization conditions as reference and design goals.
    - I think, the existing watershed conditions and historical conditions help to establish the goals and design approach.
    - Knowledge of pre-colonial conditions and post-settlement changes is poor.
    - Present watershed and reach level conditions are more appropriate than historical since watersheds typically are not like historical conditions.
    - We should not be beholden to the word or term "restoration" as it implies we are trying to go back to a condition that cannot be replicated.
    - The goal is improvement, de-listing, not to bring the stream back to some initial (pre-colonial) condition.
    - Modeled conditions (predictions) might not equal present conditions.
    - TMDL goals, what are the best opportunities?

- *Breakout Group 3*
  - Landscape and watershed context matters.
  - A possible blindspot in our stream projects is anticipating and estimating future impervious cover and the changes to the hydrology of the overall system as a result.
  - Hybrid of using historic conditions to inform design goals, as well as considering existing site limitations (ex. roads & infrastructure), esp. in highly urbanized areas.
  - Hybrid of both, historical, 1970s CWA, and current. Following up, for each level of functional pyramid, look at watershed and condition to lead to pyramid level.
  - Existing urban infrastructure and development typically acts as limitations in or influences design. Example: existing roadways being undermined by a migrating stream.
- *Breakout Group 4*
  - Availability of monitoring data is typically very limited.
  - Rush to implementation and scope of stream restoration may limit capacity to incorporate more holistically into the assessment and design.
  - Lowest bid and length of time from assessment to implementation. Extended period of time from bid to implementation that may have resulted in change in conditions prior to the start of the project; in reality there is time for pre-restoration monitoring.
  - Need to understand the historical/paleo conditions and their departure from present conditions to explain the degradation; missing base level control.
  - It was also noted there is a need to understand how the landform exists today and current constraints.
  - Looking for ‘relative stability within the ecosystem’ (all aspects of the ecosystem).
  - Temporal aspect of stability and lack of agreement or understanding what stability means (dynamic vs static).
- *Breakout Group 5*
  - Important to think of historical impairments/impacts and present when setting goals.
  - Varies in how much brought into proposal, riparian area not always considered.
  - TMDL-driven looked at holistically, want to look at historic data to determine impairment; watershed changes critical.
  - Approaches: many practitioners are more familiar with certain technique rather than many different solutions/range.
  - Are practitioners and managers open to different approaches? Or preferred approach?
    - Has gotten better over time in openness.
    - Different firms have different go-tos.
  - What are the constraints? Forests, sewer line, road crossing, fish blocking - which to eliminate to get to solution?
  - Important to look at constraints - have we always done that? Have we not thought of them before or are there more now?
    - More now, have to look at them to determine restoration or stabilization.
  - Biological conditions - ideally will want several years monitoring for present condition before restoration .
    - Many do not know anything / know little before restoration.
    - Some do, some don’t; no regulation.
    - Know some who do, is more voluntary than expected/paid for.

- *Breakout Group 6*
    - Disagreement over the relevance of historic perspective to current condition and what the current landscape can supported. Limit expectations to current landscape. Varying approaches.
    - What are we trying to achieve? What is the endpoint? Should an endpoint actually be ecology or some other metric of function which could support a healthy ecosystem.
    - Goals and approaches - still talking past each other with outcomes and approaches.
    - Most things being shown are not restoration. Sediment reduction projects? Calling things what they are.
    - Current condition - Actual modeling expected condition based on landscape limitation and benchmark observed and underperformance/overperformance against that.

What regulatory/policy drivers led to different goals and approaches?

- *Breakout Group 1*
    - Local and Bay TMDL and MS4 have pushed towards sediment management. Focus on health of tributaries would also lead to Bay health.
    - WIPs could lead to no local stream delisting.
    - TMDL leads to focus that can have negative impacts on streams stressors such as temperature and negatively impacts stream biota.
- *Breakout Group 2*
    - The two most significant drivers influencing stream restoration are mitigation and TMDL reduction projects. Probably the next driver would be voluntary restoration.
    - Mitigation requirements influence potential uplift. If an impacted site has poor stream health, then mitigation uplift requirements will be less.
        - CWA mitigation requires specific linear footage and specific benefits. Historically has favored channel form-based targets.
        - There has not been a minimum standards approach.
    - TMDL projects are water quality driven. Therefore, biological uplift goals are not primary or universal. Additionally, the simplest restoration approach to achieve TMDL reductions is often used, which also results in limited biological uplift.
        - CWA directed to impaired waters tends to focus on delisting, not restoring to reference or historic, and the delisting goal has been difficult to say the least.
        - Two types of MS4 implementation, those that felt forced which resulted in poor uplift and those that wanted uplift with their projects.
        - Streambank stabilization gets most TMDL reduction credit for the least effort.
        - Integration of TMDL reductions into MS4 permits has led to huge increases of stream restoration projects.
        - Modeled outcomes are used to obtain TMDL credits and can over predict reduction, which leads to less restoration activities.
        - Each state has adapted the Bay Program and has developed their own models to achieve credit protocols which can influence stream restoration design approach and level of effort.
        - Minimal ecological uplift with just stabilization to achieve TMDL reduction.
        - Concern over unfunded mandates and lack of staff experience.
        - Implementation and permits is often at the township level (e.g. PA).

- *Breakout Group 3*
    - TMDL Goals.
    - MS4 Permits.
    - Does the TMDL requirement lead to stream restoration becoming the first choice for BMP as opposed to other measures in N, P surface source areas?
    - To what extent do these drivers lead to expectations that we can use the stream to fix the watershed?
    - Local Gov/Community Rating for Flood Insurance.
    - Differences in regulations depending on your jurisdiction.
    - Yes, agreed, TMDL goals a driver. Also, CWA, and sensitive species protection (RTEs (rare, threatened and endangered species), coldwater, high IBI (index of biological integrity), and Tier II).
    - The optimism of functional uplift, and sometimes the extra optimism of all the way to the top of pyramid, ecological.
    - Pre-permit application analysis, then demonstration of alternatives, justification, impact avoidance and minimization, monitoring (from the wetlands & waterway regs of MD).
- *Breakout Group 4*
    - Regulatory framework is the water quality driver, engineering for water quality skews ecosystem outcomes. However, it was noted that restoration designs are not always driven by water quality goals.
    - Regulations provide minimum standards/outcomes which is better than nothing.
    - May lead to “not the right place or right design”.
    - Variability in practices despite the regulations given the influence of community values in the project. Projects often undervalue the observers (public), need to better engage and not a ‘one off’ but meaningful engagement.
    - Water quality regulatory framework pushing cost-effective approach.
    - Cautionary tale about the need for change (i.e., protocols) while considering impact on managers with a constant change makes management difficult.
    - TMDL crediting protocols drive better projects; Bay Program leading the nation.
- *Breakout Group 5*
    - Minebank Run project was protecting infrastructure.
    - More requirements for mitigation label.
    - More checks and balances to do repairs; higher standards to get repair.
    - Difference between MS4 and mitigation: wouldn’t need to plant trees if vegetation was stable, more flexible on vegetation requirement.
    - Less follow up with TMDL and MS4 than mitigation.
    - Localities with MS4 permits not going anywhere; Bay’s protocol requires going back every 5 years - don’t have capacity for much follow-up.
    - Drivers are TMDL & MS4 (urban jurisdictions), mitigation, infrastructure
        - Mitigation here: compensatory impacts (e.g. damage env, must have project to replace that damage).
    - VA rivers that have TMDL but not MS4.
    - Bay TMDL is driver in VA.
    - Goals are a range, for functional credit.

    - Might claim restoration project is a maintenance project, monitoring requirements are way lower.
    - Follow the money/funding aspect.
- *Breakout Group 6*
    - TMDL being a driver but the outcomes don't actually match up.
    - Practices fitting into the TMDL box and shooting for a different outcome.
    - Crediting system is backwards.
    - TMDL doesn't emphasize ecological restoration, it focuses on sediment and nitrogen reductions, regardless of what actually is the actual limiting stressor, even if the initial cause of listing was ecological degradation.
    - Skepticism over the Bay model that drives this.
    - Bay is actually DO outcome, despite regulating NPS. The N/P/S are means to an end on ecosystem resources, but the way it is set up makes it challenging to account for co-benefits which in local environments are actually the main benefit/cause of the initial listing.
    - EPA restricted to N/P/S due to CWA based in 1984. Introduction of Temperature TMDL has precedent and might actually help explicitly address these issues.

What are the stressors that led to stream impairment and to what degree have stream restoration approaches addressed them?

- *Breakout Group 1*
    - Unsure what stressors are, but not just sediment, and challenging to address. Temperature is rising issue.
    - Agricultural chemical runoff is issue.
    - Spatial location of pollution sources and proximity to stream important but not modeled.
- *Breakout Group 2:*
    - Stressors were identified by watershed and reach level:
        - Watershed Stressors
        - Urbanization/ Impervious
        - Water quality, often unmeasured, as toxics
        - Nutrient stressors
        - Hydrology, sediment, water quality
        - Flow regime change due to impervious cover
        - Are sediments the problem or are other water quality stressors more important
        - Deadly toxins
        - Road salts
        - Emerging contaminants of concern
    - Reach level stressors
        - Legacy sediment
        - Infrastructure
        - Nutrient stressors
        - Floodplain encroachment

        - Approaches to addressing stressors
            - Suburban/urban lead to stream hardening.
            - Water quality, often unmeasured, as toxics, and often unaddressed.
            - Legacy sediment leads to floodplain excavation.
            - Bank stabilization in urban areas.
            - Upland BMPs to address water quality and quantity.
            - High sediment loads lead to both transport and storage designs.
            - Daylighting streams in urban areas.
            - Local impervious surface removal.
            - Watershed restoration approaches.
            - Are sediments the problem or are other water quality stressors more important?
    - *Breakout Group 3*
        - Changes in hydrologic behavior of the watershed.
        - Physical changes in landscape owing to development and infrastructure.
        - Development/ land use change.
        - Legacy sediment.
        - Historic logging, mining and resulting acid mine drainage, culverts/dams, agriculture, riparian encroachment/buffer removal, chemicals like herbicides, pesticides, salts.
        - Private encroachment limits uplift designs.
        - Incised channels limit improved floodplain connection/interaction.
        - Many projects do not identify the numerous stressors causing stream impairments but are rather focused on obtaining nutrient and sediment loading for credits.
        - Loss of soil moisture storage capacity in developed watersheds.
        - Loss of tree canopy can increase stream water temperatures, and stream restoration slows down water allowing additional warming. Riparian reforestation allows for cooling and so do large canopy trees once they grow.
        - The role of legacy sediment is more complex than the way it is typically represented. There is a lot of disagreement among geomorphologists about its role. In some places removal is justified. In other places, channels with thick legacy sediment are migrating very slowly and pose no problem.
        - Much of what is written talks about fine sediment. But coarse sediment may be a bigger factor, along with altered hydrology, in causing channel instability.
        - Hydrology & hydrograph, in two words.
        - Interesting thought about legacy sediments separate from hydrology and hydrograph.
        - Urban watershed syndrome has more impairments than just sediment.
        - Impervious cover/development increased flows limiting increasing residence time through design approaches (floodplain benches etc.).
    - *Breakout Group 4*
        - Use and application of threshold designs (e.g., example of threshold designs and minimum width required). If the models simulate thresholds, if not able to obtain these thresholds then you are doing something else other than restoration.

  - Many others but challenge to get regulatory buy-in e.g. water > ancillary benefits.
- *Breakout Group 6*
  - Urban areas, not addressing them 100%. Can't handle big slugs of water, Heat, asphalt road seal/PAH death drop**,** flows.
    - Maybe rural areas, there is success, which have degradation flow that can be restored.
    - Acid mine drainage reasonably easily treated. Acid precipitation is better.
    - Agricultural pesticides.

Has the monitoring of outcomes been effective and sufficient, including biotic uplift?

- *Breakout Group 1*
  - Monitor the whole watershed area to detect cumulative impacts of management, not just project footprint. No.
  - Too often minimum effort to meet permit requirements.
  - Better goals lead to better monitoring. Should be independent/unbiased 3rd party entity doing monitoring. Could use high-res land use data to help plan and monitor.
- *Breakout Group 2*
  - Need before and after data.
  - Often no pre-restoration water quality monitoring.
  - Not good comparisons pre- and post-restoration, biotic often based on best available habitat instead of representative habitat.
  - PA and MD regulatory now requiring more detailed monitoring to demonstrate project success (e.g., monumented survey, full photo doc, conditional assess, as-built design).
  - What should be the time scales? Vegetation is a factor in success.
  - Are goals of projects stated?
  - Rarely even get assurance that project, as built to show project was constructed as designed, or modeled.
  - More effort needed to share data with practitioners.
  - Grant funding doesn't include monitoring. MS4 staff not always capable. Operating funds not always available.
  - Can't use capital funds for monitoring, this creates problems.
  - Monitoring prior to stream work is difficult with grant funding and short timelines.
- *Breakout Group 3*
  - There is room for improvement. More in-depth monitoring prior, and more diversity of parameters post-restoration.
  - If we don't have long-term monitoring efforts, we don't know if these projects work. Even so results are often inconclusive.
  - We have heard this morning that biotic uplift almost never occurs in urban watersheds.

    - For an urban setting, we clearly need to define another metric that isn't primarily water quality or macrobenthic invertebrate focused (ours do improve things, despite not resulting in the return of brook trout).
    - Figuring out the watershed-scale effectiveness of individual restoration projects is very difficult.
    - No, monitoring of stream restoration outcomes has not been effective or sufficient.
    - Helpful, and growth area, but not sufficient!....yet as far as effectiveness, reasonably so, given resources available (as mentioned by others).
    - Very significant growth area, to help analyze valid alternatives in the future, plus justification and inform design.
- *Breakout Group 4*
    - Historically, science informed regulations such as the CWA, how can this be incorporated into restoration outcomes today given understanding of lag times.
    - 5-year cycles to meet goals.
    - While there wasn't a direct answer to this question, the input from the breakout session from other questions would infer the answer is "no".
    - Basis for restoration to set the stream on trajectory of recovery, use of models.
    - Disconnect between expectations and timelines.
    - Meeting goals even though dissolved oxygen levels have decreased.
    - Not valuable to "monitor everything everywhere".
    - A lot of data, need for more data that informs rather than 'more data'.
- *Breakout Group 5*
    - No.
    - Design perspective: so concerned about stability goals, overdesigning.
    - Can't have erosion in arrested stream bank or can't get credits.
    - Monitoring in stability of project not necessarily TMDLs.
    - A lot of monitoring is structural.
    - Scrutiny of monitoring depends on driver (more monitoring for mitigation).
- *Breakout Group 6*
    - People generally don't think they have been effective or sufficient? Monitoring on form versus process? Disagreement about metrics and outcomes.
        - Standards issue that the channels don't move. Longitude, cross section, veg, bugs. Bugs 20 sq ft proportional to available habitat. Success cross-section can't change more than 20%, profile can't change more than Y%. 400 stems per acre.
        - Some comments about not having the methods and techniques to properly evaluate new approaches, which traditional methods were not developed for.
        - Don't have standardized methods that are appropriate to system.
        - Can improve metrics and have targeted metrics.

When outcomes have been successful, why where were they successful? What has worked?

- *Breakout Group 1*
    - Headwater streams has worked better, due to less hydrologic issues to manage.
    - Create buffer of space for stream to be dynamic, and focus on long-term

    equilibrium.
  - Avoid high quality streams. Thorough search for impaired reaches to restore, not focus on available land.
- *Breakout Group 2*
  - Designer understood stressors and designed a stream that would naturally form and be self -sustaining.
  - Simple stressor to fix.
  - Small watersheds, which are the most abundant, are also the easiest to "fix" (with some constraints).
  - Ample funding available to achieve project goals.
  - Good understanding of objectives and they were obtainable.
  - Site selection based on goals.
  - Watershed stressors (sources) reduced.
  - Increasing heterogeneity of small watershed responses also helps bigger watersheds.
- *Breakout Group 3*
  - In DC, a full connection of the upper portion of stream to the downstream waterbody has allowed for the return of upstream habitat (Nash Run).
  - Reducing P and N. There's been success for reducing TMDL loads.
  - The upcoming STAC report states that we have been successful reducing N and P loads from point sources. Nonpoint sources, not so much.
  - Some of the improvement comes from the success of Clean Air Act regulations.
  - There is a big disconnect between the load predictions of the Bay watershed model and what the river monitoring data tell us. Measured loads don't show the reductions predicted.
  - This is not about stream restoration but about large-watershed response. Do watershed loads reflect changes from individual sites? Unclear at best.
  - Daylighting!
  - Lots of lateral room allows for a larger buffer and true habitat restoration (e.g. Springhouse Run).
  - Ancillary benefits. Anadromous fish returning/breeding.
  - It is possible to stabilize and create an aesthetically pleasing restoration even if other objectives are not met. The criteria for success should reflect what is feasible at each site.
  - Dam removals and culvert replacements that have facilitated improved aquatic organism passage and hydrology.
  - When restoration goals were science based and restoration design was focused on meeting those goals.
  - I hear not everyone loves the functional pyramid, but it definitely has helped with goals, objectives, and results assessment, so appreciation of that.
  - A bit more expense, time, and expertise needed but retaining larger trees within the project area (where possible).
- *Breakout Group 5*
  - Difficult to gauge, not enough pre- and post- monitoring to know what did(not) work and what improved.

    - Disagree - stream calculator updated, restoration protocol updated, methodologies to evaluate credit is improving.
    - Very credit-driven, not accounting for function?
        - Getting better at credit aligning with function, incentives for restoration projects.
    - Appropriate goal differs.
- *Breakout Group 6*
    - Disagreement on the are actually the outcomes? In rural areas,
        - People generally considered that bugs would be degrading, but new analysis showing that this improvement has been happening at 6% since 2008, almost 10% since 2005? But no idea why or what is under those data.. Look forward to seeing data and report (Buchanan et al. 2023).
        - Reforestation of certain areas, atmospheric deposition changes and reductions through Clean Air Act (acid and nutrients).

Day 3 Breakout Session Responses

The second breakout session started at the end of Day 2 and continued into Day 3. Participants were requested to consider how we can achieve desired outcomes. Questions asked were the following:

1. What are the challenges and opportunities to design a stable stream? Do you think stability increases ecosystem uplift?
2. How will our work change?
3. What is preventing us from moving forward to meeting our outcome?
4. What do we need to change to better align with achieving our outcome?
5. What are your recommendations for moving forward?

Day 3, Breakout Group Responses

What are the challenges and opportunities to design a stable stream? Do you think stability increases ecosystem uplift?

- *Breakout Group 1*
    - Unsure what stressors are, but not just sediment, and challenging to address. Temperature is rising issue.
    - Agricultural chemical runoff is issue.
    - Spatial location of pollution sources and proximity to stream important but not modeled.
- *Breakout Group 2*
    - Daylighting: pulling streams out of pipes! whenever possible (opportunity). Also really helps with public perception/acceptance
    - Mismatch between project objectives and proposed restoration solutions/project design.
    - Challenge of site limitations (existing roads/crossings, high shear stresses resulting from watershed conditions).
    - Need to decide on how we define "stable" for the purposes of stream restoration.
    - Do we have empirical evidence that stability increases uplift? Is “stability”

  clearly enough defined to answer this?
  - Stable streams may be poor for biology.
  - Some stability can increase ecological uplift - depending on the design. Rip rap does not! Incorporating ecological features does.
  - Opportunities- if site conditions allow, go beyond stabilization as a goal to incorporate natural features that may increase ecological uplift.
  - Understanding of sediment transport for different particle sizes is important.
  - Stability may or may not help with ecological uplift - what is the ecology you are designing for?
  - Constraints may require geomorphic lock down, but that should be the exception rather than the rule.
  - Most streams in urban and suburban watersheds have sanitary sewers either under the channel or under adjacent riparian zone - a critical constraint.
  - Challenge: Maybe we aren't using the best metrics for monitoring the improvements of "restored" streams? (particularly in an ultra-urban enviro) = hard to show progress.
- *Breakout Group 4*
  - Moving to a more collaborative, team approach from multiple perspectives; acknowledge lack of agreement in restoration outcomes/design approach.
  - Seeing a more positive outlook with the surge in research that is pushing the discipline to mature and advance rapidly.
- *Breakout Group 5*
  - Better understanding that stream ecosystems have a range of historical variability (in ecosystem structure or process), i.e. they are not naturally static or stable/stuck. Consider stressors in the watershed.
  - Do alternative analysis to determine what designs would work, what would be trade-offs.
  - Update design standards and guidelines.
  - Site selection process could improve. For instance, new technology should be used to look at entire stream and determine problematic areas; possibility of looking at multiple sites for restoration.
  - Require biological data monitoring before designing project; consider research protection; quantitative analysis of effect of design, holistic overview so don’t cause more harm than good.
  - What prevents meeting design outcomes? incentives/money.
  - Consider social perception of stream restoration.
- *Breakout Group 6*
  - We have different assessment techniques for streams - which assessment methods actually match - benthic macroinvertebrates to quick rapid assessment. Series of methods developed for these relationships in Europe, including biological response to restoration.
  - Permitting limitations with other designs beyond bankfull channel design, which explicitly prohibit some geomorphic function and process, like natural adjustments which are key to local function.

How will our work change?

- *Breakout Group 2*
  - New/altered monitoring metrics and guidance.
  - I would like to see a separate designation for urban streams. How to define? Percent IC (Impervious Cover)? Density? Other?? These are not the same systems as in the suburban/rural areas.
- *Breakout Group 5*
  - Changing climate.
  - "In-stream habitat restoration" projects are often designed to lock streams in place.
  - Natural streams are not stationary. The goal of a stable channel should be one that adjusts to conditions, which requires floodplain space.
  - Existing human development (roadways, sanitary sewers, etc.).
  - Disturbance/instability can be a valuable ecological trait, resetting or enabling ecological processes.

What is preventing us from moving forward to meeting our outcome?

- *Breakout Group 1*
  - Wicked problem.
  - Better pre- communication among regulators and practitioners. Set reasonable expectations.
  - Definition of "restoration" is important to distinguish goals. Greater pre-restoration ecological monitoring to better understand the impairments. More monitoring to understand outcome – success or failure. Clear criteria for where to do projects, and where not to do projects (e.g. high quality streams).
  - Should be actionable.
  - One aspect could be future changing land use.
  - Does stream need restoration, and specific practice/approach, regardless of available land?
  - Forensic analysis of project outcomes to enable adaptive management. TMDL and MS4 makes incentives that does not lead to goal of ecological uplift. Need stream corridor restoration legislation Monitoring resources. Inability to have long-term resources or focus to do adaptive management.
  - Paleo research to understand historic condition.
- *Breakout Group 2*
  - Pursuit of credits and cost/profits by funders and implementers.
  - Failure to address or reduce the primary stressors.
  - Cost effectiveness ($/lb) and crediting vs. ecological uplift.
  - May need different incentives for appropriate strategies in urban streams.
  - The requirements of the TMDL are creating incentives that may not be consistent with the site- or watershed-specific needs.
  - Often site selection is constrained by private property rights and choices are made to do something where you can get permission which may not be the optimal location.
  - Time scale needed for proper assessment of success may be 10-20 years.

  - Conflicting standards (?) by ACE districts and state regulators.
  - Wanting to build a "completed" project rather than an adjustable design, due to both local and regulatory interests.
  - How to establish performance standards that allow for changing systems and that all parties can agree to.
  - Sediment reduction projects are taking place without documenting erosion rates that document the problem, justify the intervention, and inform design.
  - Conflicting regulations between state/fed/local; and FEMA.
  - The public is less enthusiastic about invasive projects, maybe this presents opportunities for iterative designs.
  - CBP can help with this by developing a high quality outreach campaign that would be applicable Bay-wide (vs. coming from the jurisdiction behind the project!).
  - Projects identified by willing landowners instead of a comprehensive watershed restoration plan along with mismatched restoration goals and expectations.
  - Over-estimation of sediment reduction.
  - Public resistance due to lack of understanding, lack of a Bay-wide educational campaign to explain the benefits of good streams and the problems with bad!
  - Failure to understand what made projects successful.
  - If stream restoration is a first resort because less expensive per TMDL credit the incentive may work against including watershed-scale strategies.
  - Inertia.
  - Lack of funding for incentivizing things other than TMDL (ecological uplift, in-depth, science-backed monitoring).
  - Proper communication with the public to demonstrate benefits of stream restoration.
- *Breakout Group 4*
  - Moving to a more collaborative, team approach from multiple perspectives; acknowledge lack of agreement in restoration outcomes/design approach.
  - Seeing a more positive outlook with the surge in research that is pushing the discipline to mature and advance rapidly.
  - A call for the review of the science every 5 years (recommendation in protocols).
  - Recommend taking an ecosystem approach and then water quality an ancillary benefit.
  - Incorporating the valley/riverscape/corridor as part of restoration.
  - Clear goals and expectations that are shared; “humanize” valley restoration with community buy-in and monitoring.
  - Setting a trajectory of recovery.
- *Breakout Group 5*
  - Better understanding that stream ecosystems have a range of historical variability (in ecosystem structure or process), i.e., they are not naturally static or stable/stuck. Consider stressors in the watershed.
  - Do alternative analysis to determine what designs would work, what would be trade-offs.

    - Update design standards and guidelines.
    - Site selection process could improve. For instance, new technology should be used to look at entire stream and determine problematic areas; possibility of looking at multiple sites for restoration.
    - Require biological data monitoring before designing project; consider resource protection; quantitative analysis of effect of design, holistic overview so don't cause more harm than good.
    - What prevents meeting design outcomes? incentives/money.
    - Consider social perception of stream restoration.

What do we need to change to better align with achieving our outcome?

- *Breakout Group 1*
    - Lighter touch where possible.
    - Slow down projects to better evaluate if stream would benefit from restoration.
    - More accurate crediting model to reflect likely outcome.
- *Breakout Group 2*
    - New metric for gauging progress for urban stream restoration.
    - A high quality outreach campaign for bad streams and good streams that would be applicable Bay-wide and directed for the public!
    - Identification of which sites could provide significant downstream improvements.
    - Defining criteria for de-listing 303D impairments.
    - Actually document problem (quantify vs visual assessment).
    - Stronger emphasis on local benefits than pounds of sediment, N and P saved which distorts incentives.
    - Monitor for ecological outcomes.
    - Learn from failures, copy successes.
    - Address watershed sources first.
    - Stream restoration should not be considered in isolation from other watershed BMPs - need integrated strategies for headwaters and downstream.
    - Design for uplift to specific ecologic processes.
    - Identify socio-ecological needs/priorities at across scales.
    - Landscape matters - it affects design and ecological potential.
    - Require that all projects are part of compressive comprehensive watershed plans that identify watershed stressors and prioritize accordingly - look upland not to channel to fix.
    - Focus on preserving soil moisture holding capacity.
    - Build resilient projects (climate/trajectories/etc).
    - Ease of access should have less influence in site selection.
    - Science/policy research (do regulations dictate relevant success criteria? Do policies and regulations yield or benefit poor or less beneficial projects?).
    - Increased storm intensity is increasing urban runoff in older suburbs, causing demands for stormwater control.
- *Breakout Group 4*
    - Incorporating the valley/riverscape/corridor as part of restoration.

    - Clear goals and expectations that are shared; “humanize” valley restoration with community buy-in and monitoring.
    - Setting a trajectory of recovery.
- *Breakout Group 5*
    - Increases in impervious (and developed pervious!!) cover. Greater inputs to the "restored" stream further stressing the restoration.
    - And we may need a separate set of criteria for urban streams.
- *Breakout Group 6*
    - Having the ability to change success metrics - Meander frequency, bankfull depth.

What are your recommendations for moving forward?

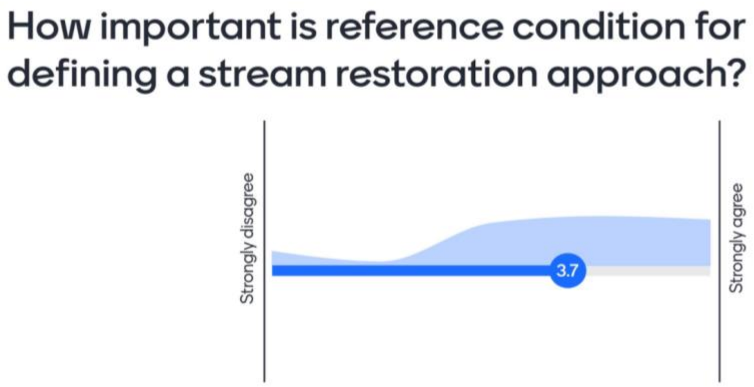
- *Breakout Group 1*
    - Landscape specific considerations.
    - Protect watersheds better to reduce the need to do stream restoration.
    - Restoration should only improve and not worsen streams.
    - Public education on messaging about negatives of stream impairment and improve crediting to include other ecosystem services.
    - Build thermal considerations into planning and projects.
    - Continue coordination and build and trust the larger structured process.
    - Support other BMPs and management that will support conditions for uplift. Improved siting and pre-project data collection to identify biological impairments and causes.
    - Identify which methods work best for specific conditions and goals and be realistic.
    - Planning for future changes (e.g. climate and land use) in stream restoration designs.
- *Breakout Group 2*
    - We need to be far more rigorous in choosing projects. Credits for sediment reduction need to be reexamined.
    - More projects, better projects, higher expectations.
    - Better incentives/policy/regulations that focuses on watershed restoration and reach level ecological uplift.
    - More focus on soil moisture retention - lack of soil moisture retention creates many of the problems we use stream restoration to fix.
    - Setting a "high" bar for stream interventions.
    - Change the weighting of reach-scale TMDL sediment, N and P credits as compared with local watershed-scale benefits.
    - Define de-listing procedures for local TMDLs. Particularly for benthic impairments (stressor=sediment).
    - More emphasis on stressors, controlling runoff, salt contaminants near the sources.
    - Defining "realistic" goals.
    - Develop a separate set of criteria for urban watersheds and streams.
    - Allow for stream dynamics in policy/regulation/public information.
    - Improve understanding of social drivers of restoration and how that informs

    - and/or interacts with restoration decisions and ecological outcomes.
    - Set the bar. Require that projects are part of comprehensive watershed plans.
    - We are looking skeptically at where restoration is being done and why.
    - No intervention to degraded streams is a decision.
    - Determine how social decisions are affecting the project implementation process.
- *Breakout Group 4*
    - A call for the review of the science every 5 years (recommendation in protocols).
    - Recommend taking an ecosystem approach and then water quality an ancillary benefit.
- *Breakout Group 5*
    - Use models for alternative analysis.
    - Look more at successful biological outcomes to see what is possible, what was done (used as examples).
    - Consider areas that can be protected and enhanced.
- *Breakout Group 6*
    - Reform of the crediting system; Documentation about previous resource condition at a site; standard reporting system; exposing the data that we already have.
    - Regulatory improvements for making sure that places aren't unraveling, better monitoring, more targeted to the outcome.

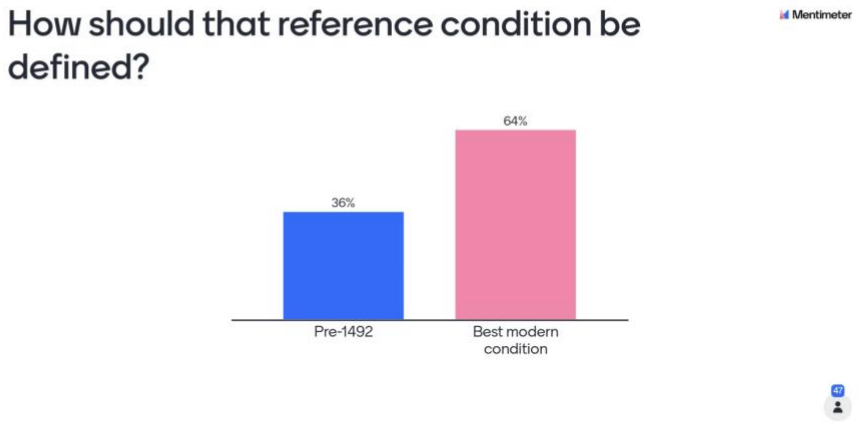
Group Poll Results

In-person and virtual participants were asked to respond to predetermined questions using a digital poll platform. All responses collected were anonymous. Questions asked were the following:

- How important is reference condition for defining a stream restoration approach?
- How should that reference condition be defined?



46 workshop attendees responded to the first question on the importance of a reference conditions for defining a stream restoration approach. On a scale of 1-5, with 1 indicating “strongly disagree” and 5 “strongly agree”, the average score across respondents was 3.7. Participants answered by sliding from left to right depending on their answer. The distribution of votes is seen above the slider.



For the second question, 47 workshop attendees responded on how the reference condition mentioned in question 1, should be defined. Respondents were given two choices: pre-1492 and “the best modern condition.” 64% (30 participants) voted for best modern condition. Participants were allowed to vote once.

Appendix D: Stream Restoration Definitions

The following list of terms are often misunderstood or lack clarity, leading to a variety of interpretations. We attempt to provide some guidance on working definitions and urge that practitioners, regulators, and researchers clearly define these terms in all communication.

1) Ecosystem Functions – The biotic and abiotic processes within an ecosystem (Leuzinger and Rewald, 2021). More specifically, ecosystem functions are the ecological processes that regulate the fluxes of energy, nutrients, and organic matter through an ecosystem. An ecosystem function should be distinguished from a functioning ecosystem. The latter refers to the dynamic interaction of an ecosystem as a functional unit with its environment. An individual function may be as simple as "provide habitat" or "process nitrogen (or nutrient cycling)." In contrast to ecosystem functions, ecosystem structure represents the biotic and abiotic components of the system. Ecosystem functions specific to streams include but are not limited to: retaining or transmitting sediment; biogeochemical cycling (retaining and releasing nutrients, or producing and processing carbon, etc.); providing habitat and refuge for aquatic and riparian organisms; creating corridors for migration; surface water transient storage; and flow/flood control. It is important to note also that not all functions will be of equal importance in all landscapes. Understanding ecosystem functions will help planners and designers formulate alternatives and assess the relative benefits and impacts of each. However, the component/parameter of the function should be well-described, and the monitoring metrics selected to measure changes in those functions in order to assess restoration outcomes.

Below are examples of ecosystem functions and a few examples of approaches to evaluate changes to ecosystem functions. Additional examples of ecosystem functions related to stream corridor restorations are below (this is not an all-encompassing list; Table A4-1).

Example 1: In streams restored to improve habitat one could measure 1) changes in the amount of habitat or diversity of habitats known to be used by organisms for one or more of their life history needs (i.e. recruitment, growth & development, reproduction, shelter, etc.); or, 2) the biotic response to specific or collective habitat(s).

Example 2: In streams restored to enhance nitrogen retention one could measure 1) changes in nitrogen annual loads, yields, or concentrations of dissolved inorganic nitrogen; 2) nitrogen uptake rates through nitrogen addition experiments before and after restoration; 3) denitrification rates in the channel sediment, floodplain or both using ^{15}N.; or 4) changes in nitrogen storage in riparian and floodplain soils.

Example 3: In streams restored to improve the capacity of the ecosystem to provide goods and services that satisfy human needs, one could measure 1) how the community rates the restored stream regarding scenic quality; 2) changes in the number of people visiting the restored stream for pleasure or recreation.

Table 1. Ecosystem functions of streams that could be evaluated for changes due to stream restoration.

Function	**Indicators**	**Metrics**
Sediment dynamics	Retain and export sediment, maintains the channel stability expected for the basin geomorphology and land cover, substrate sorting.	Bed material sediment loads and gradations. Suspended sediment load assessments. Stability assessment techniques. Erosion and deposition rates. Changes in channel geometry. Sediment yield measures. Sediment transport modeling.
Biogeochemical	Regulates essential processes such as nutrient spiraling (uptake, retention and release); cycling of nutrients and carbon between biotic and abiotic components.	Biogeochemical functional proxies of C and N inputs such as leaf litter decomposition, concentrations of nutrients dissolved oxygen (DO) and dissolved organic matter (DOM), other key parameters such as temperature, conductivity, rates of key processes such as denitrification and DO consumption, phosphate sorption/desorption, and stable isotope ratios of various pools and substrates such as plants, animals, sediments, and DO.
Life systems support	Synthesis of organic matter and exchange of energy	Dissolved oxygen concentration, gross primary productivity, change in carbon storage, and ecosystem respiration
Habitat and refuge provision for diverse aquatic and riparian organisms	- Supports life systems by providing food, water and shelter for animals and plants - Provides suitable environmental conditions for fish and other organisms to live and reproduce.	Diversity of physical stream features/habitat, riparian species diversity, riparian vegetation composition, and structure. Riparian zone width.
Migration corridor	- Supports migration of aquatic and terrestrial organisms in the stream channel and riparian zone	Riparian zone width, tree density, fish passage, mist nets, etc.
Hydrodynamic balance, discharge regulation	Supports the natural hydrological variability of the stream type and the flow conditions that maintain the appropriate biotic environment for organisms during different seasons, Transient surface water storage, flow/flood control	Streamflow flashiness, shape of storm hydrographs, ratio of baseflow to stormflow in annual discharge, channel geomorphology assessment, floodplain water storage during storms.

Table A4-1. Ecosystem functions of streams that could be evaluated for changes due to stream restoration.

2) Functional Uplift – The improvement of one or more ecosystem functions through a restorative activity. These can be physical, chemical, and biological processes, often tied to measurable parameters (Harman et al. 2012).

Example: A ‘priority 1’ stream restoration project raised the streambed and reconnected the channel with the floodplain. As a result, the ground water table was raised an average of 2 feet throughout the floodplain, allowing more consistent, cooler, and permanent baseflow in the stream channel and reduced peak flows among other hydrological improvements. Each individual ecosystem function improved indirectly by raising the ground water level and reconnecting the floodplain should be considered a functional uplift.

3) Ecological Uplift – The improvement of biotic and/or abiotic components or groups within an ecosystem. Successful ecological uplift can be shown by the improvement of one or more biotic or abiotic factor. Improving the biophysical characteristics (physical form and/or biology) of a stream that create greater functional capacity should be considered ecological uplift.

Example 1: Increasing floodplain ground water table allows nitrate-rich water transported from the watershed to the channel as subsurface flow to interact with the organic matter (living and non-living) in floodplain sediments, promoting denitrification and nitrogen loss. Increased access to ground water also promotes nutrient uptake by roots. Additionally, if the water table elevation increase results in more consistent stream base flow, numerous aquatic organisms should benefit. In both cases organisms will benefit from increased interaction with groundwater.

Example 2: Reducing bank erosion and adding coarse woody debris increases the availability of high quality habitat within the stream channel. As a result, indices of benthic macroinvertebrate communities improve, indicating biotic uplift as part of functional uplift.

4) [Stream] Restoration – The manipulation of a stream, riverscape, or riparian corridor to restore a previously degraded function. The concept of previous function(s) is vague, and can refer to geomorphology, hydrology, hydraulics, habitat, water chemistry, water quality, or biology. “Stream restoration” is a catchall term used to describe a wide range of management actions and as such is difficult to define. The definition of stream restoration can vary with the perspective or discipline of the practitioner or with the temporal and spatial scale under consideration” (Simon, 2011). **We recommend that stream restoration projects use modifiers to add specificity to allow for greater understanding and not just label everything as "restoration."** For example, stream restoration as an objective could include specific goals of “channel geomorphic stabilization” or "aquatic biology improvement," or both, or more.

The most accepted definition of *ecological* restoration was published in the Society of Ecological Restoration Primer on Ecological Restoration. It states that ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed." (Gann et al. 2019).

A definition of *stream* restoration is the return of a stream ecosystem's structure and function to a state that is more reflective of its pre-disturbance form (Murdock, 2008).The Army Corps of Engineers' Nationwide Permit #27 -'Aquatic Habitat Restoration, Enhancement, and Establishment Activities,' indicates restoration is defined as the manipulation of the physical, chemical, or biological characteristics of a site with the goal of repairing natural/historic functions to a former aquatic resource. (Federal Mitigation Rule, 2008).

5) Reference or Reference Condition – Generally, a reference [site] or reference condition is used to describe a standard or benchmark against which the current/restored site or condition is measured. (Stoddard, Hawkins, and Stevenson 2017). Temporal and/or landscape standards or benchmarks should be explicit when discussing comparisons and experimental designs that include a "reference." Reference sites indicate potential form and function and reflect conditions to which native biota are adapted and should be thought of as a continuum rather than a binary [pristine vs. degraded] goal (Wohl; this workshop).

Examples: In the context of the project's watershed, biological and geomorphic conditions are often compared to known or modeled conditions based upon an appropriate time in the past such as: pre-colonial, pre-industrial, pre-1972 (Clean Water Act enactment), or pre-2010 (Chesapeake Bay TMDL). Additionally, reference sites or conditions may refer to the best available location/condition, adjacent sites/conditions to an area of development or restoration activities, or a paired watershed with similar conditions. Due to the broad use of the term "reference", clarity is needed on temporal or landscape determination of a reference site or condition. **We recommend that stream restoration projects clearly identify the reference condition used to design and assess the restoration.**

6) Riverscape, River or Riparian Corridor, Stream System – Inclusive of the water, organisms, and other material in the channel (bed and banks), the adjacent active or historic geomorphic connected floodplain, and the riparian zone (Harvey and Gooseff 2015, Wohl et al. 2021).

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Appendix F: List of Figures

Appendix G: List of Tables

Appendix H: STAC Workshop Proposal

The State of the Science and Practice of Stream Restoration in the Chesapeake: Lessons Learned to Inform Better Implementation, Assessment and Outcomes

Proposal for a STAC State of the Science Workshop

Submitted by: Stream Health Workgroup

Steering Committee Members (all have confirmed their participation):

1. Greg Noe, USGS and STAC, Co-Chair
2. Neely Law, Fairfax County and Stream Health Workgroup, Co-Chair
3. Bill Stack / Lisa Fraley-McNeal, Center for Watershed Protection
4. Joe Berg, Biohabitats
5. Sadie Drescher, Chesapeake Bay Trust
6. Solange Filoso, University of Maryland Center for Environmental Studies
7. Paul Mayer, EPA
8. Chris Ruck, Fairfax County
9. Rich Starr, Ecological Planning and Restoration
10. Scott Stranko, MD DNR

Background

Since 2010, jurisdictions throughout the Chesapeake Bay Watershed (CBW) have implemented approximately 266 miles of stream restoration with an additional 84 miles planned as reported in the Phase 3 Watershed Implementation Plans. The extent of project implementation driven by nitrogen, phosphorus and sediment (N/P/sed) load reductions required by the Chesapeake Bay TMDL will result in large-scale effects on aquatic ecosystems. Although Chesapeake Bay Program (CBP) expert panels have determined that stream restoration leads to N/P/sed load reductions to improve the health of the Chesapeake Bay, the effects on other local stream ecosystem attributes is less certain. Motivation for restoring streams also extends beyond load reductions and can include functional uplift to improve the status of aquatic biota and riparian corridor habitat as well as geomorphic stabilization to protect infrastructure. The rapid increases in stream restoration implementation throughout the CBW have led to growing concern and controversy about the effects of stream restoration on whole-ecosystem health and services. Although assessment of outcomes of stream restoration projects has been notoriously limited (Bernhardt et al. 2005), over time more studies have documented the results of stream restoration practices that allows the opportunity to summarize these new findings. The time is right to bring together the scientific and management communities to synthesize our understanding of practices, assessment approaches, and ecosystem outcomes in order to inform and improve stream restoration practices.

Workshop Objectives

The overall purpose of the workshop is to bring together a diverse cross-section of experts and stakeholders in the field of stream restoration to review and distill lessons learned from past stream corridor restoration projects to improve restoration outcomes. For the purposes of this workshop, stream restoration is broadly defined as an intervention to move a degraded ecosystem to a trajectory of recovery as informed by a reference condition considering local and global environmental change. The scope of the workshop includes the riparian area.

The workshop will be focused on three topics:

1. Identify the evolution of stream restoration goals, regulations, practices and practice implementation;
2. Present and discuss science and assessment to document holistic impacts and outcomes; and
3. Create a synthesis of the best available science, practices and monitoring to enable adaptive management.

Management Relevancy

This workshop will build upon the scientific literature, previous workshops and expert panels to synthesize current knowledge that supports adaptive management in the implementation of stream restoration projects with the goal to improve project outcomes. As part of the preparation for the workshop, we will develop a literature database of relevant publications. This database will be a shared product and be used to guide literature review and synthesis.

The proposed workshop will build upon past CBP and STAC efforts. We will use the findings of Stream Restoration crediting protocols (Urban Stormwater Workgroup, 2014-2021), as well as a prior workshop on stream restoration that identified the need to consider functional based assessments (STAC, 2015). The Stream Health Workgroup also is currently reviewing the known stressors to stream health (USGS, expected 2022).

Improved understanding of stream restoration outcomes is directly related to the goals of multiple CBP Goal Implementation Teams (GIT), Workgroups (WG), and Outcomes. The proposed workshop will primarily benefit the Stream Health WG, Forest Buffer outcome, and Urban Stormwater WG. The Stream Health Outcome is to continually improve stream health and function throughout the watershed, and their Work Plan (2022-24) includes an action to convene a STAC workshop on stream restoration. The Forest Buffer Outcome is to continually increase the capacity of forest buffers to provide water quality and habitat benefits throughout the watershed. The Urban Stormwater WG has the goal to have all practices and controls installed to achieve the Bay's dissolved oxygen, water clarity/SAV and chlorophyll *a* standards as articulated in the Chesapeake Bay TMDL document. The findings of the workshop also are relevant to the scope of the Maintain Healthy Watersheds GIT, Brook Trout Action Team, and Wetlands WG.

In addition, stakeholders throughout the Chesapeake watershed are continuing to implement large numbers of stream restoration projects. A synthesis of the state of the science and practice of stream restoration is essential to support adaptive management given the decade or more of experience with the Chesapeake Bay watershed and nationally. Through this workshop, we can reinforce communication, understanding, and development of prioritized information gaps to improve the practice of stream restoration and to suggest targeted scientific needs to support the implementation of practices that best meet stakeholder needs.

Why a STAC Workshop

There is a diverse group of stakeholders that are involved in stream restoration projects. The STAC workshop provides a unique opportunity to focus on the science and how science influences and is influenced by regulation, practice (design & engineering) policy, and programs of stream restoration. A STAC workshop is uniquely capable of recruiting and engaging across the diversity of geography, professions, institutions that are involved in stream restoration while providing a forum to collect and synthesize the best science available. In addition, a STAC workshop is extremely effective at disseminating critical findings to the CBP partnership and other organizations.

Workshop Preparation and Planning / Logistics

Phase 1: Pre-workshop Planning

Since the workshop is intended to occur in winter 2022 or early spring 2023, the Steering Committee will commence planning quickly after STAC approval. They will start with at least one planning meeting per month for the first three months and hold more frequent meetings as necessary as the workshop date gets closer. The early planning discussions among the Steering Committee will refine specific workshop questions to focus workshop content, conversations, and outcomes. A literature review will also commence. At the same time, the Steering Committee will compile a list of desired workshop presenters and participants, consisting of CBP GIT and Workgroup representatives, state and local personnel responsible for planning, overseeing, or regulating, researchers and NGOs, practitioners, and more.

Phase 2: Workshop Structure

The workshop will consist of a 2 or 2 ½ day onsite meeting (virtual if necessary). The agenda will feature particular topics and questions, as identified elsewhere in this proposal and to be further refined. The workshop will end with a working session among all attendees, guided by the Steering Committee to develop specific "SPURR" recommendations that will inform the final report. Prior to the workshop, the steering committee will develop specific questions to tease out recommendations from the participants during the working session.

Phase 3: Workshop Follow-up

Within 90 days of the workshop, the steering committee will use the feedback and consensus on potential actions from the workshop participants to develop a set of recommendations in the "SPURR" format in the final workshop report.

Due to the technical nature of this topic, we would prefer to host this workshop in person to ease discussion and collaboration among workshop participants. We would plan for the possibility of hosting this workshop virtually if necessary, using a meeting platform provided by STAC with break-out rooms for discussion. After the completion of the final workshop report, the Steering Committee and other workshop participants will commence the writing of a scientific review paper for submission to a peer-reviewed journal.

Expected Outcomes

We envision at least five products from the workshop. First, a better engaged community of practitioners and scientists. Second, a STAC report to provide a detailed summary with actionable outcomes for the Chesapeake Bay Program and stakeholders. Third, an updated catalogue of the relevant published literature on stream restoration. Fourth, communication and presentation of findings to interested parts of the CBP. Fifth, a peer-reviewed scientific paper that synthesizes available information for a global audience.

As stream restoration is one of the most common management actions to meet the Chesapeake Bay TMDL, and streams are essential to many CBP GITs and WG, we envision the workshop will lead to better stream restoration projects through improved understanding of stream health and management – throughout the CBP, the region, and the world.

Speaker Topics/ Questions to Address

1. Opening plenary: The Chesapeake Bay Watershed history and evolution of: stream degradation patterns, trajectories, and sustainable ecosystem states (including channel evolution models), stream restoration goals, and restoration approaches. Additionally, the plenary may address questions such as, "What is the "reference" condition?", as informed by science and stakeholder input, and "What should we restore towards and repair?"
2. Goals, Resource Tradeoffs and Unintended Consequences – Describe the typical goals of stream restoration in the Chesapeake, including a comparison of goals for the managed stream reach (e.g. biotic functional uplift, and stabilization) vs downstream waters (e.g. load reduction, and attenuating peak discharge). What approaches are needed to resolve the differing goals that may conflict?
3. Regulatory/Permitting – The history and influence of the regulations and their impact on stream restoration design.
4. Restoration Outcomes and Uplift: Present and discuss the evidence of outcomes from monitoring stream restoration projects and measuring defined (or not) outcomes, including research and permits. Topics may include holistic assessment of stream ecosystem response, timescales of response, and identification of strategic knowledge gaps. How are stakeholders and researchers working together to advance adaptive management of stream restoration?
5. Stressors and Landscape/Climate Change –Are reach-scale stream restoration practices ameliorating the stressors to stream health, or do other watershed derived stressors determine stream outcomes? What factors are able to be modified to alter a stream towards recovery and what variables are outside of our control. What are the temporal and spatial scales of landscape and climate change that influence streams and stream restoration? This topic may also include the topic of larger scale restoration projects and connectivity.

Appendix I: Links to Workshop Recordings

Workshop recordings can be found on the STAC Workshop webpage and linked below.

Session 1: Identify the evolution of stream restoration goals, regulations, practices, and practice implementation (after 1972 Clean Water Act)

- Opening Plenary: Watershed History and Evolution of Stream Degradation Patterns and Restoration – Ellen Wohl (CSU), Presentation Recording
- Opening Panel with Q&A: The Chesapeake Nontidal Watershed History and Evolution of Stream Degradation Patterns and Restoration – facilitated by Ben Hayes (Bucknell), Panel Recording
    - Panelists: Dorothy Merritts (Franklin & Marshall College); Karen Prestegaard (UMd); Andy Miller (UMBC); Matt Cashman (USGS); Kevin Smith (Maryland Coastal Bays Program)
- Outcomes from Stream Restoration in the Past (pre-2010 period of Chesapeake Bay Agreement) – facilitated by Tess Thompson (VT), Panel Recording
    - Ecology and Water Quality Speaker: Scott Stranko (MD DNR) and Bob Hilderbrand (UMCES)
        - Ecology panelists: Nancy Roth (TetraTech), Dave Penrose (Penrose Environmental Consulting), Solange Filoso (UMCES)
    - Stream Stabilization Speaker: Rich Starr (Ecosystem Planning and Restoration)
        - Stream Stabilization panelists: Scott Lowe (McCormick Taylor); David Wood (CSN); Bill Stack (Center for Watershed Protection)
- Lessons Learned from the Past – Ben Hayes (Bucknell), Presentation Recording

Session 2: Present and Discuss Science and Assessment to Document Holistic Impacts and Outcomes (2010-present)

- Regulatory/Permitting and Policy: Parameters for showing success – facilitated by Rich Starr (Ecosystem Planning and Restoration), Panel Recording
    - Maryland – Denise Clearwater (MDE)
    - Virginia – Brock Reggi (VA DEQ)
    - Pennsylvania –Jeffrey Hartranft (PA DEP)
- Detailed case studies of individual stream restoration projects – facilitated by Chris Ruck (Fairfax County) and Joe Berg (Biohabitats), Panel Recording
    - Legacy Sediment – Robert Walter (Franklin and Marshall College)
    - Coastal Plain – Joe Berg (Biohabitats)
    - Urban – Josh Burch (DC DOEE)
    - Suburban – Chris Ruck (Fairfax County)
- Restoration Outcomes and Uplift – facilitated by Sadie Drescher (Chesapeake Bay Trust), Panel Recording
    - In-channel biotic – Mark Southerland (TetraTech)
    - Stabilization – Tess Thompson (VT)
    - Water quality (including geomorphic restoration for WQ) – Paul Mayer (EPA)
    - Riparian –Lisa Fraley-McNeal (Center for Watershed Protection) and Meghan Fellows (DE Center for Inland Bays)

Session 3: Create a Synthesis of the Best Available Science, Practices and Monitoring to Enable Adaptive Management (future)

- Closing Plenary: The Future of Environmental Recovery is Dependent on a Paradigm Shift that Embraces the Past – Erik Michelsen (Anne Arundel County), Presentation Recording