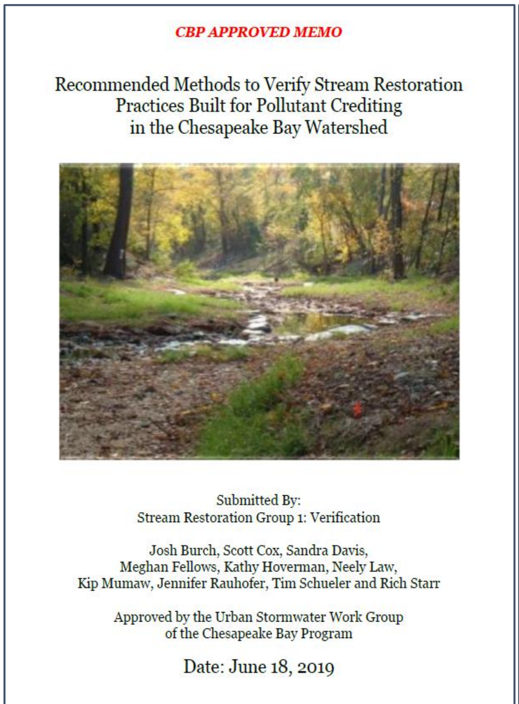
A Unified Guide for Crediting Stream and Floodplain Restoration Projects in the Chesapeake Bay Watershed


CBP APPROVED MEMO

Recommended Methods to Verify Stream Restoration Practices Built for Pollutant Crediting in the Chesapeake Bay Watershed

Submitted By:
Stream Restoration Group 1: Verification

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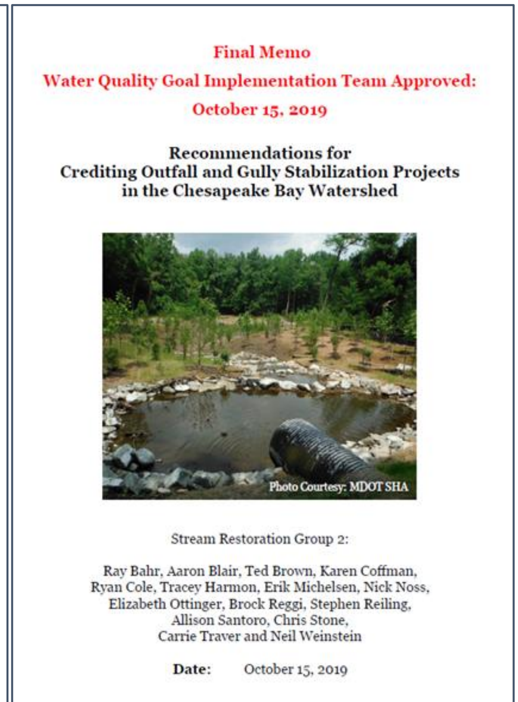
Approved by the Urban Stormwater Work Group of the Chesapeake Bay Program

Date: June 18, 2019


Final Memo
Water Quality Goal Implementation Team Approved: October 15, 2019

Recommendations for Crediting Outfall and Gully Stabilization Projects in the Chesapeake Bay Watershed

Photo Courtesy: MDOT SHA

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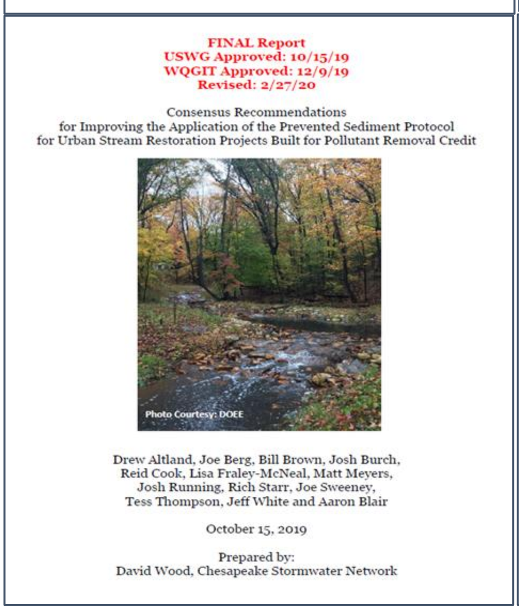
FINAL Report
USWG Approved: 10/15/19
WQGIT Approved: 12/9/19
Revised: 2/27/20

Consensus Recommendations for Improving the Application of the Prevented Sediment Protocol for Urban Stream Restoration Projects Built for Pollutant Removal Credit

Photo Courtesy: DOEE

Drew Altland, Joe Berg, Bill Brown, Josh Burch, Reid Cook, Lisa Fraley-McNeal, Matt Meyers, Josh Running, Rich Starr, Joe Sweeney, Tess Thompson, Jeff White and Aaron Blair

October 15, 2019

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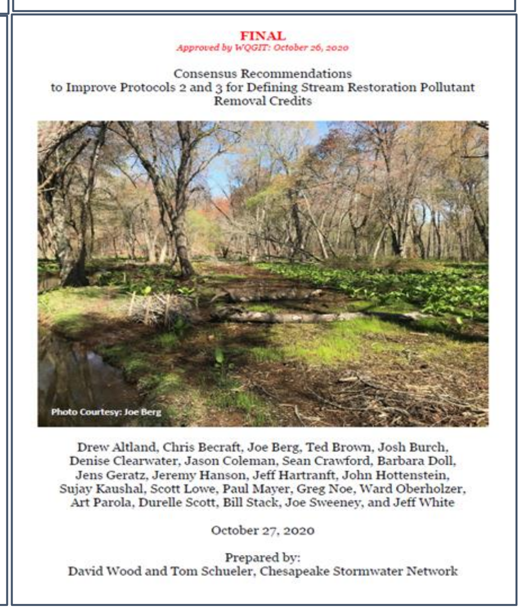
FINAL
Approved by WQGIT: October 26, 2020

Consensus Recommendations to Improve Protocols 2 and 3 for Defining Stream Restoration Pollutant Removal Credits

Photo Courtesy: Joe Berg

Drew Altland, Chris Becraft, Joe Berg, Ted Brown, Josh Burch, Denise Clearwater, Jason Coleman, Sean Crawford, Barbara Doll, Jens Geratz, Jeremy Hanson, Jeff Hartranft, John Hottenstein, Sujay Kaushal, Scott Lowe, Paul Mayer, Greg Noe, Ward Oberholzer, Art Parola, Durelle Scott, Bill Stack, Joe Sweeney, and Jeff White

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The Chesapeake Bay Program Partnership works to involve all restoration stakeholders in an inclusive process to find consensus on complex technical and policy issues involved in Bay restoration. In our case, we would like to recognize the great efforts by local, state and federal members of the Urban Stormwater Workgroup, Watershed Technical Workgroup, and the Water Quality Goal Implementation Team. These three groups were responsible for the thorough review, vetting and approval of the individual memos over the years, along with the input and sage counsel of the Agricultural, Forestry and Stream Health Workgroups.

We also want to thank the many talented staff at the Chesapeake Bay Program Office in Annapolis, Maryland who provided technical support to ensure consistency with the Chesapeake Bay watershed model, CAST and other partnership tools. Thanks to Gary Shenk, Jeff Sweeney, Olivia Devereux, Jess Rigelman, Lucinda Power, Vanessa Van Note, Jeremy Hanson, Mark Dubin and Loretta Collins.

Preface

Over the last decade, Bill Stack, David Wood and I have all had the privilege to work with these impressive stream experts to facilitate technical consensus on crediting stream restoration practices implemented for the Chesapeake Bay TMDL. We have distilled two expert panels, five expert memos, 34 technical appendices and more than 250 scientific references into a single, integrated and condensed reference. The goal was to provide a single, reliable guide for stream practitioners and Bay managers to answer their questions when it comes to crediting stream restoration projects. With this in mind, we offer the following caveats to all our readers:

This guide provides no new technical information , beyond what was approved in the most recent reports and memos. Our goal is to alert readers to the many key changes in the protocols since the original expert panel was approved back in 2014.

Our editing philosophy was simple: respect the consensus decisions and specific intent of the stream experts who developed the guidance, but work hard to make it concise, clear, consistent and readable, while keeping the bureaucratic fluff to a minimum. The guide is organized to provide the most essential details that Bay managers, and stream practitioners need to know, with rapid links to other technical resources needed to use the protocols.

The BMP review process is science-driven and the stream experts spent a great deal of time reviewing the state of stream restoration science. We have reorganized their research syntheses into a single stream science "index", which readers are encouraged to consult to understand the technical rationale for how the protocols were developed.

Readers who want to read the precise language of the earlier memos and reports can access them in the table below:

Links to the Core Approved Stream Restoration Documents
2019 Protocol 1 Guidance: Full Report: https://chesapeakestormwater.net/download/9928/ 2020 Protocols 2 and 3 Guidance: Full Report: https://chesapeakestormwater.net/download/10032/ 2019 Outfall (Protocol 5) Guidance: Full Report: https://chesapeakestormwater.net/download/9714/ 2019 Verification Guidance: Full Report: https://chesapeakestormwater.net/download/9621/

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Chapter 3: Bay Managers Guide to the Stream Restoration Practice

Chapter 1
Basics of Bay Stream Restoration Crediting

Section 1.1 Essential Chesapeake Bay TMDL Context

To fully understand stream restoration in the Chesapeake Bay watershed first requires some background on the Chesapeake Bay Total Maximum Daily Load (TMDL) and the process for reviewing Best Management Practices (BMPs). The Chesapeake Bay TMDL was established in 2010, and set limits on nitrogen, phosphorus, and sediment that enter the Bay. The TMDL is designed to ensure that all pollution control measures, needed to fully restore the Bay and its tidal rivers are in place by 2025.

To be eligible to count toward the TMDL nutrient and sediment limits, all BMPs must go through a rigorous review and approval process. Each potential BMP is reviewed by a panel of experts comprised of academics and practitioners from the public and private sectors. The Expert Panel develops a report that establishes the official practice definitions, qualifying conditions, pollutant removal calculations, and reporting and verification requirements. The final report is then subjected to an extensive public comment and response period before being approved via full consensus by three different Chesapeake Bay Program stakeholder workgroups.

As of 2021, there are 15 approved BMP expert panel reports for the urban stormwater sector, covering several dozen individual practices (Table 1). The final version of the Stream Restoration Expert Panel report was approved in 2014.

Table 1. Summary of Approved BMP Expert Panel Reports Relevant to the Stormwater Sector

BMPs for New and Redevelopment	Enhanced Erosion and Sediment Control
Stormwater Retrofits	Floating Treatment Wetlands
Urban Stream Restoration	Advanced Septic System Upgrades
Urban Nutrient Management	Impervious Cover Disconnection
Street Cleaning and Storm Drain Cleanout	Urban Tree Canopy Expansion
Nutrient Discharges from Gray Infrastructure	Riparian Buffer Plantings
Residential Stewardship Practices	Shoreline Management Practices
Non-Tidal Wetland Restoration	

Due to advancements in science and policy, some BMP expert panel reports are revisited over time to update the nutrient and sediment reduction calculations and/or reporting requirements. The four new memos reflect this process for stream restoration practices.

Section 1.2 Key Terminology and Boundaries

The stream experts agreed on a common language to guide practitioners and managers when it comes to crediting stream restoration projects. Some of the important terms include:

Floodplain – For flood hazard management purposes, floodplains have traditionally been defined as the extent of inundation associated with the 100-year flood, which is a flooding event that has a one-percent probability of being equaled or exceeded in any one year[1]. However, in the context of this document, floodplains are defined as relatively flat areas of land between the stream channel and the valley wall that will receive excess storm flows when the channel capacity is exceeded. Thus defined, water accesses the floodplain much more frequently than what is typically considered a flooding event.

Headwater channels – Stream segments connected to open or closed channel segments within zero to first order channels where water first originates in a stream system. These channels can be ephemeral, intermittent, or perennial and often adjust to storm flows through gully and rill formation and therefore can produce significant vertical and lateral rates of erosion.

Hyporheic Zone – A zone located below a stream and extending into the floodplain, occupied by a porous medium where there is an exchange and mixing of shallow groundwater and the surface water in the channel. The dimensions of the hyporheic zone are defined by the hydrology of the stream, substrate material, its surrounding environment, and local groundwater sources. This zone has a strong influence on stream ecology, biogeochemical cycling, and stream water temperatures. It is also the zone where nitrogen processing is highest and where denitrification occurs, especially when groundwater interacts with plant roots in the floodplain soil layer. This layer is typically rather shallow, often only 9 to 18 inches deep in most streams/floodplains (see Figure 1).

Legacy sediment – Legacy sediments are defined as sediment stored in the valley bottoms as a byproduct of accelerated erosion caused by landscape disturbance following European settlement (Miller et al 2019). The presence and subsequent breaches of mill dams throughout the mid-Atlantic region and the Chesapeake Bay watershed, commonly lead to channel incision, bank erosion and increased suspended sediment loads (Merritts et al 2011).

Sediment eroded from uplands over several centuries accumulates behind dams in slack-water environments, resulting in thick deposits of cohesive clay, silt and sand along stream corridors and within valley bottom that effectively buries natural floodplains, streams and wetlands (see Figure 2). Legacy sediments

[1] Floodplain management agencies use the term one-percent-annual chance to define this event, in part to dispel the misconception that the 100-year flood occurs once every 100 years. In this report, return periods instead of probabilities are used for convenience.

impair many stream and floodplain functions, and are typified by low channel pattern development, infrequent inundation of the riparian zone, diminished sediment storage capacity, habitat degradation, and lack of groundwater connection to floodplain and/or riparian areas.

Outfalls – The outlets, conveyances and discharge points from storm drain networks, often located at headwater stream systems or are direct connections to closed storm drain networks. Does not include outfalls that produce overflows from separate or combined sewer systems

Prevented sediment **–** The annual mass of sediment and associated nutrients that are retained by a stable, restored stream bank or channel that would otherwise be eroded and delivered downstream in an actively enlarging or incising urban stream. The mass of prevented sediment for an individual stream restoration project using the field methods and Protocol 1.

The stream experts defined the specific zones in the stream corridor where the pollutant removal credits apply, and how their spatial boundaries are established, as follows:

Project Reach: The length of an individual stream restoration project as measured by the valley length (expressed in units of linear feet). The project reach is defined as the specific work areas where stream restoration practices are installed, and the same crediting protocol(s) are applied.

Bank Erosion Zone (BEZ): This is the zone along the project reach where the overall rate of lateral bank retreat is measured before and after a channel is restored, which is a key input into the prevented sediment protocol. Streambank stabilization techniques are used in the restored project to diminish the potential for future erosion at critical points along the post-restoration stream bank.

Effective Hyporheic Zone (EHZ): The area of restored channels and floodplain wetlands used to calculate nitrogen reduction credits using Protocol 2. A zone located below and alongside a stream, occupied by a porous medium where there is an exchange and mixing of shallow groundwater and the surface water in the channel. The dimensions of the hyporheic zone are defined by the hydrology of the stream, its substrate and surrounding environment, and local groundwater sources. (See Figure 3)

Floodplain Trapping Zone (FTZ): The area where low energy conditions encourage trapping and filtering of sediments and organic matter in the floodplain during and shortly after storm events. Extends from the floodplain surface to one foot above the baseline floodplain elevation, unless a higher elevation is justified by local hydrologic and hydraulic modeling[2]. (See Figure 4)

Floodplain Reconnection Volume (FRV): This term quantifies the benefit that a given project may provide in terms of bringing streamflow in contact with the

[2] Maryland practitioners should follow guidance from MDE, found here.

floodplain. The FRV is defined as the additional annual volume of stream flow that is effectively diverted onto the available floodplain, riparian zone, or wetland complex, over the pre-project volume (see Figure 5).

Headwater Transition Zone (HTZ): The zone connecting upland land uses and urban drainage (swales, ditches and storm drain pipes) discharging stormwater discharges into the perennial stream network. Slopes or channels within the zone typically lack perennial or seasonal flow. These zones experience higher rates of both vertical and lateral erosion and are responsible for high sediment delivery to downstream reaches. Prevented sediment in the HTZ is usually calculated using Protocol 5 (see Figure 6).

Section 1.3 Review of the Supporting Stream Science

Stream restoration is an evolving practice rooted in the science of hydrogeomorphology. This science has developed Channel Evolution Models (CEM's) which have helped stream restoration practitioners categorize a stream's geomorphic form, pattern and profile and to suggest evolutionary trajectories from which to base design.

The panel of experts recognized that these models are global in nature and cannot account for differences in soils, slope, physiography and watershed constraints, requiring that practitioners use a combination of design approaches relying on basic engineering science (e.g., hydraulics, sediment transport). Therefore, no one approach is favored over another within this document.

Like the practice of stream restoration, the science behind its sediment and nutrient load reduction benefits are evolving, requiring multiple scientific disciplines such as geo-chemistry, wetlands, and biology. Our understanding of the scientific processes related to the processing of nutrients has significantly advanced over the last decade. This section describes the science-driven process to understand the pollutant removal dynamics of restored and non-restored streams and floodplains, and how it guided the development of the crediting protocols**.** While we are not offering a new research synthesis, we have organized the technical summaries into the stream science categories in the box below. Readers are encouraged to consult the links within to learn more about the supporting research that the experts relied on**.**

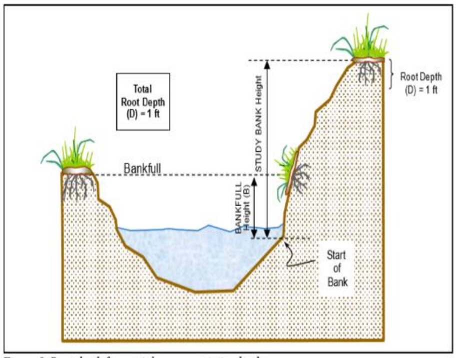
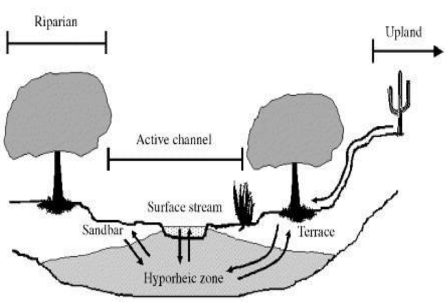
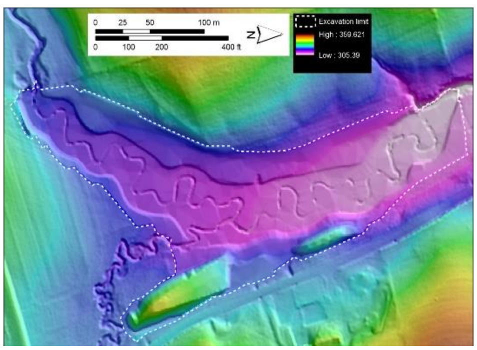
Table 2. Stream Science Index	
Stream Science Category	*Summary and link to report excerpts*
Basic Streambank Erosion  *Figure 5. Root depth for partial grass vegetation bank coverage*	Numerous studies have shown streambank erosion to be one of the major contributors of sediments to the Chesapeake Bay. Stream sediments can also be a rich source of nutrients and therefore an important contributor to the Bay's eutrophication. Basic Streambank Erosion Science
Headwater Sediment Discharge 	Within the stream network, the headwater transition zone acts as a watershed "hotspot" for sediment erosion and downstream delivery. The headwater transition zone has many characteristics that promote high rates of erosion and sediment delivery such as storm drain outfalls, steep slopes, unconsolidated soils and limited floodplain area. Headwater Sediment Discharge Science
Hyporheic Denitrification 	Researchers have found the groundwater–surface water interface (hyporheic zone) to be a zone of active nitrogen transformation. Several studies have shown that stream restoration projects that have increased groundwater residence time resulted in denitrification hot spots in the hyporheic zone, particularly when sufficient organic carbon is available to the system. Hyporheic Denitrification Science

Table 2 (Continued)	
Stream Science Category	*Summary and link to report excerpts*
Floodplain Trapping 	Several studies within the Chesapeake Bay watershed have shown sediment and nutrient trapping rates in reconnected floodplains can be similar to "natural" floodplains. Therefore, restoring the stream and floodplain system will ultimately improve nutrient and sediment retention capacity in well-designed restoration projects. Floodplain Trapping Science
Legacy Sediments 	One of the most comprehensive long-term monitoring studies of a floodplain restoration project is the Big Spring Run project in Pennsylvania, that investigated ecosystem responses to a project that removed legacy sediments from the valley bottom. Preliminary results have shown this project to be highly effective in reducing both the concentration and mass loads of upstream nutrient and sediments. Legacy Sediment Science
Unintended Consequences 	It is generally acknowledged that restoration project construction often exerts short-term adverse environmental impacts. Depending on the pre-restoration condition and level of construction disturbance, years of ecosystem maturation may be needed before a project fully meets its long-term restoration objectives and realizes its full environmental benefits. Unintended Consequences Science
For a complete list of references, please access the following link.	

Section 1.4 Stream Restoration Design Approaches

The discipline of stream restoration has spawned many different design approaches and terms; therefore, the panels agreed on the following definitions and acronyms that appear within this document.

Stream restoration **-** Refers to any natural channel design (NCD), regenerative stormwater conveyance (RSC), legacy sediment removal (LSR) or other restoration approach that meets the qualifying conditions for credits, including environmental limitations and stream functional improvements. No single design approach was considered superior, as any project can fail if it is poorly located, assessed, designed, constructed, or maintained.

Natural Channel Design (NCD) - Application of fluvial geomorphology to create stable channels that maintain a state of dynamic equilibrium among water, sediment, and vegetation such that the channel does not aggrade or degrade over time. This class of stream restoration utilizes data on current channel morphology, including stream cross section, plan form, pattern, profile, and sediment characteristics for a stream classified according to the Rosgen (1996) classification scheme, but which may be modified to meet the unique constraints of urban streams. Figure 7 provides some typical examples of NCD stream restoration projects.

Regenerative Stormwater Conveyance (RSC) - Refers to two specific classes of stream restoration as defined in the technical guidance by Flores (2011) and An (2018). The RSC approach has also been referred to as coastal plain outfalls, regenerative step pool storm conveyance, baseflow channel design, and other biofiltration conveyance. Figure 8 provides some typical applications of RSC projects.

For purposes of this report, there are two classes of RSC: dry channel and wet channel.

> *Dry channel RSC* involves restoration of ephemeral streams or eroding gullies using a combination of step pools, sand seepage wetlands, and native plants. The receiving channels are located above the water table and only carry water during and immediately after storms. Protocol 4 is used to define pollutant reduction achieved by this stormwater retrofit treatment practice.
>
> *Wet channel RSC* are located in intermittent streams or further down the perennial stream network and use in-stream weirs to spread storm flows across the floodplain at minor increases in the stream stage during smaller storm events. Wet channel RSC may also include sand seepage wetlands or other wetland types in the floodplain that increase floodplain connection, reconnection, or interactions with the stream. Wet channel RSC systems are classified as a stream restoration practice, and their pollutant removal rate can be estimated based on a combination of Protocol 1, 2 and 3.

Floodplain Restoration (FR) - In the past, many urban stream restoration designs focused on channel geometry to accommodate the flows and sediment inputs to the project reach. While floodplain reconnection was often considered, reconnection in these designs only occurred several times a year during larger storm events. Over time, scientists and practitioners have realized the importance of reconnecting the stream with its floodplain. Designers now seek to restore streams and floodplains together, using a diversity of design approaches borrowed from NCD, LSR, RCS and other sources, as long as there is floodplain area available and means to reconnect it with the stream. Practitioners generally take one of two basic design approaches to reconnect incised streams with their floodplains (Table 3).

Table 3. Comparison of the Two Major Floodplain Restoration Strategies

Factor	Floodplain Restoration Strategy	
	LSR Legacy Sediment Removal	**RSB** Raised Stream Bed
Strategy	"Lower the Floodplain"	"Raise the Stream"
Design Approach	Legacy sediments are removed to restore the floodplain, which reduces bank heights, expands hyporheic exchange, and reconnects a stream or increases existing connection of a stream to its floodplain and aquifer	Raise the stream bed either by (a) filling incised channels and/or (b) installing riffle/grade control practices To effectively lower bank heights, raise the shallow groundwater into the root zone, and more frequently access the floodplain
Boundaries and Zones	Both share common zones such as EHZ and FTZ, but use different indicators and field methods to define their precise vertical and lateral boundaries	
Floodplain Plant Community	Restore historical floodplain plant community (often wet meadow complexes)	Wider range of potential floodplain habitat outcomes, e.g., could also be forest, scrub-shrub, wet meadow, or emergent wetlands

- *Raising the Stream Bed (FR-RSB)* - Involves one of two techniques to raise the elevation of an incised stream channel and shallow groundwater, thereby increasing the volume of runoff diverted into the floodplain for treatment. The first technique fills the incised channel with native materials to elevate the stream invert, thereby increasing the annual stream runoff volume diverted into the floodplain. The second technique installs a series of elevated riffle grade control structures or beaver dam analogues to slow flow velocities and promote floodplain access during storm events.

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- *Legacy Sediment Removal (FR-LSR)* - A class of aquatic resource restoration that seeks to remove legacy sediments to lower the floodplain, enhance hyporheic functions and increase the annual stream runoff volume diverted into the floodplain. LSR also can reconnect the floodplain with its hyporheic aquifer, thereby enhancing aquatic resources including such as streams, floodplains, and palustrine wetlands. Although several LSR projects have been completed, a major experimental site was constructed in 2011 at Big Spring Run near Lancaster, PA. Figure 9 provides some typical examples of LSR stream restoration projects.

Outfall and Gully Stabilization (OGS) - Practices that use an engineering approach to design a stable channel to dissipate energy that extends from the upland source to the stream channel. Figure 10 shows some pre-restoration photos of severe vertical erosion experienced at stormwater outfalls and gullies in the headwater transition zone. The new channel is designed and constructed to achieve an equilibrium or near-equilibrium state where future sediment loss is minimized or eliminated altogether.

Acceptable OGS practices provide a permanently stable connection between upland runoff sources and receiving streams by utilizing structural energy dissipation techniques such as grading, step-pools, cascades, and rock toe protection within the typically steep headwater transition zone. At highly constrained sites, other stable engineering solutions such as drop structures, extension of existing storm drain pipes or scour protection may be considered. Some examples of acceptable OGS practices are shown in Figure 11.

Qualifying Conditions: Regardless of the design approach taken, all TMDL restoration projects must meet stringent qualifying conditions before any credits can be earned. The key qualifying conditions can be found in Section 3.1.

The qualifying conditions are designed to promote a watershed-based approach for stream restoration projects that improves stream function and habitat. In particular, the qualifying conditions help ensure stream restoration is directed to areas of severe stream impairment, and that the proposed project carefully considers the restoration needs of the stream, and the potential for functional uplift (see Figure 12).

Section 1.5 Summary of the Crediting Protocols

The 2014 Expert Panel conducted an extensive review of recent research on the impact of stream restoration projects in reducing the delivery of sediments and nutrients to the Bay. A majority of the Panel decided that the past practice of assigning a single removal rate for stream restoration was not practical or scientifically defensible, as every project is unique with respect to its design, stream order, landscape position and function.

Instead, the Panel crafted four protocols to define the pollutant load reductions associated with individual stream restoration projects. This section provides an updated summary of what are now five protocols that can be used to earn pollutant removal credit. More details on each protocol are provided in Chapter 2, but some of their basic features are profiled below:

Protocol 1: Credit for Prevented Sediment during Storm Flow -- This protocol provides an annual mass nutrient and sediment reduction credit for qualifying stream restoration practices that prevent channel or bank erosion that would otherwise be delivered downstream from an actively enlarging or incising urban stream. The size of the credit depends on the length of the project, the measured rate of bank retreat, and the height of the eroding streambanks.

Protocol 2: Credit for Instream and Riparian Nutrient Processing during Base Flow -- This protocol provides an annual mass nitrogen reduction credit for qualifying projects that include design features to promote denitrification during base flow. Qualifying projects can receive credit under Protocols 1 and 3, and use this protocol to determine enhanced nitrogen removal through denitrification within the effective hyporheic zone during base flow conditions. The size of the credit is related to the size of the effective hyporheic zone, the presence of carbon sources, groundwater flows, the connection to the floodplain and aquifer conductivity

Protocol 3: Credit for Floodplain Reconnection Volume -- This protocol provides an annual mass sediment and nutrient reduction credit for qualifying projects that reconnect stream channels to their floodplain over a wide range of storm events. Qualifying projects receive credit for sediment and nutrient removal under Protocols 1 and 2 and use this protocol to determine enhanced sediment and nutrient removal through floodplain wetland connection.

A wetland-like treatment is used to compute the load reduction attributable to floodplain deposition, plant uptake, denitrification and other biological and physical processes. The size of the credit depends on the elevation of the stream invert relative to the stage elevation at which the floodplain is effectively accessed. Designs that divert more stream runoff onto the floodplain during smaller storm events receive greater credit than designs that only interact with the floodplain during infrequent events, such as the two-year storm event.

Protocol 4: Credit for Dry Channel RSC as an Upland Stormwater Retrofit-- This protocol computes an annual nutrient and sediment reduction *rate* for the contributing drainage area to a qualifying dry channel RSC project. The rate is determined by the volume of stormwater treatment provided in the upland area using the retrofit rate adjustor curves developed by the Stormwater Retrofit Expert Panel.

Protocol 5: Credit for Outfall and Gully Stabilization (OGS) Practices. This protocol is an adaptation of the prevented sediment protocol that is applied to highly incised channels in the headwater transition zone that are experience severe vertical erosion problems The goal is to create a stable channel that dissipates energy extending from storm drain outfalls to the stream network. The new channel is reconstructed to achieve an equilibrium state where future sediment loss is minimized or eliminated altogether.

The size of the credit depends on the degree of vertical incision encountered in the headwater transition zone.

Section 1.6 Other Important Stream Crediting Concepts

The Bay manager and the stream practitioner should acquire a keen understanding of several important crediting concepts which are described below:

Functional uplift - A general term for the ability of a restoration project in a degraded stream to recover hydrologic, hydraulic, geomorphic, physiochemical, or biological indicators of healthy stream function.

Unintended Environmental Consequences **-** Stream restoration projects have the potential to exert unintended environmental consequences, particularly if they are poorly assessed, located, designed or constructed. Unintended environmental impacts have been observed in restored stream channels, floodplains and downstream ecosystems (see Figure 13). All stream restoration design approaches (i.e., NCD, RSC, LSR and their variants) have the potential to cause unintended consequences.

Short-term adverse impacts are common during and shortly after construction, followed by project adjustment and recovery over several years. These impacts should be considered in relation to the stressors measured in a comparable unrestored urban stream/floodplain system. The potential for unintended environmental consequences can be reduced when "best practices" are adopted during restoration project planning, design, and construction. These best practices are described in detail in Chapter 2, are advisory in nature, and may not apply to every individual project or application.

Bank armoring - Armoring involves the placement of hard structures along the stream channel for the express purpose of limiting the movement of a stream along its horizontal and/or vertical dimensions. Engineers use bank armoring to protect and fix streams within constrained urban stream corridors so they will not move or erode at design flow rates and shear stress. For purposes of Protocol 1, individual bank armoring techniques are classified as being creditable, creditable with limits or non-creditable. Some examples of non-creditable, limited credit and creditable bank armoring practices can be found in Figures 14a, 14b and 14c.

Project verification - Is required to ensure that any practice used for pollutant reduction credit in the Chesapeake Bay TMDL actually exists, is working as intended and are maintained properly over their design life. Each urban BMP has a defined credit duration, which can only be renewed when a field inspection of visual indicators confirms that the practice continues to function properly. The credit duration of stream restoration practices is five years.

Visual indicators **-** Protocol-specific rapid field assessments that measure potential loss of pollutant reduction function in some or all of the project reach for dominant restoration crediting protocol. Visual indicators are used to quantify obvious departures from original design that appear to compromise project pollutant reduction functions. Some examples of visual indicators used in field investigations can found in Figure 15.

Project failure **-** Field crews use numeric failure thresholds to determine the length of a project reach that may be compromised during field verification inspections. A second forensic investigation by a qualified stream restoration professional may be needed to confirm the diagnosis. Projects are assessed using visual indicators to determine if the degree of change is severe enough to warrant management action, relative to the original design. Stream restoration projects are classified as either functioning (pass) showing major compromise (action needed) or failing (fail, and lose credit).

Links to Learn More:
Full Stream Restoration Glossary List of Acronyms Complete Reference List

Chapter 2:
Practitioner's Guide for Applying the Protocols

This chapter is targeted to stream practitioners, which refers to an interdisciplinary team of stream professionals, that collect key data to assess, design, permit, construct and verify individual stream restoration projects. They are also the ones that calculate and confirm pollutant reduction credits back in the office using one or more of the approved protocols in the Chesapeake Bay watershed. Practitioners include consultants, permit reviewers, engineers, ecologists, biologists, construction managers and others, and may work for both the public and private sector.

The purpose of this chapter is to provide practitioners with all the information they need to know to manage individual stream restoration projects built for TMDL pollutant reduction credit. The chapter is organized as follows:

- Pre-construction Assessment and Site Monitoring
- Application of the Five Crediting Protocols
- Project Construction and Documentation
- Post-Construction Verification Investigations

Section 2.1 Pre-Construction Assessment and Site Monitoring

This section outlines the key site information to collect to determine if a project meets the qualifying conditions for credit, the data or tests needed to support the protocols, and the best practices to follow during project planning and design.

2.1.1 Best Practices for Project Planning and Design

The stream experts developed a series of best practices to guide practitioners as they evaluate and design potential projects. Some of their key recommendations include:

1. Planners should evaluate options for combining stream and floodplain restoration with stormwater, forestry and agricultural BMPs in the contributing watershed area. It is generally accepted that individual stream and floodplain restoration projects are more effective when pollutant loads delivered from the contributing watershed also are reduced.

2. Identify and remedy site-specific source(s) of impairment in the stream and floodplain (e.g., sedimentation, flow alterations and/or habitat degradation). Use both reference form and processes to assess impairment and provide the basis for restoration designs. Individual project designs should apply the restoration principles outlined by EPA (2000).

2. Follow guidance from the appropriate federal, state or local regulatory authority regarding how existing high-quality habitat and ecosystem functions are assessed. The following are considerations that may be required:

- Assess existing habitat characteristics and functions across the project during project planning and design phases and compare with predicted post-construction conditions to evaluate uplift
- Conduct intensive surveys when high quality stream or wetland resources are identified within or immediately downstream of the project reach to assess potential impacts to these resources
- Avoid restoration projects at sites where aquatic assessment metrics indicate that the stream is currently in good or excellent condition.
- Avoid restoration projects at sites where floodplain or wetland metrics indicate that the current floodplain plant community is functioning well.
- Carefully survey existing forests to minimize tree clearing during construction and identify individual trees that should be saved.

3. Give special consideration to protecting freshwater mussels and their host fish if they are present within or immediately downstream of the project reach. Common, rare, threatened and endangered species all deserve conservation consideration per the findings of Kreeger et al (2018). The site should be surveyed for mussels as soon as possible. Freshwater mussels can be inconspicuous and as such a thorough survey is important.

4. Site designs should consider the presence of live mussels and avoid disturbances. It may be helpful to view their presence similar to infrastructure or wetlands (Blevins et al. 2019). Mussels represent one of the priority species of conservation in these ecosystems, and as such stream restoration designs which leads to known disturbance of these organisms would be counterproductive and inappropriate.

5. Ensure that all aquatic life (e.g., fish, eels, etc.) can safely pass through the project reach through careful design of instream structures. Passage may be accomplished by aquatic life moving through, over, or around instream structures.

6. Avoid designs that:
   - Create stagnant pools within the stream channel and long-term inundation or ponding across the floodplain width. Creation of vernal and temporary pools within the floodplain as a habitat feature is acceptable.
   - Rely on extensive bank armoring using rock or other fixed structures and disregard the maximum armoring limits adopted by Group 3 (2020).

    - Dewater perennial stream channels. Rather, irrigation curtains and other techniques can be used to maintain consistent baseflow conditions.

7. Clearly describe how the proposed project will affect local and downstream elevations of the 100-year floodplain, and conform to federal and state floodplain management requirements through appropriate H&H modeling.

8. Assess potential for toxics contamination in floodplains located within highly urban areas or brownfields and watersheds that have a history of potential contamination through soil investigations. Avoid disturbing acidic soils if they are present at the project site.

2.1.2 Ensure Restoration is Appropriate for the Stream

Important project qualifying conditions are outlined in detail in Chapter 3, which deserves a careful read. This section looks at the basic issue of whether a TMDL-driven stream restoration project is actually appropriate for the stream reach/floodplain in question. Some of the critical qualifying reach conditions that practitioners should carefully consider are:

- The stream reach must be greater than 100 feet in length and be still actively enlarging or degrading in response to upstream development or adjustment to previous disturbances in the watershed (e.g., a road crossing and failing dams).

- Most projects will be located on first- to third-order streams, but can be targeted on fourth and fifth order streams if found to contribute significant and uncontrolled amounts of sediment and nutrients to downstream waters.

- The project must utilize a comprehensive approach to stream restoration design, addressing long-term stability of the channel, banks, and floodplain. Pending site conditions/constraints, the most ideal designs reconnect the stream with its floodplain and create wetlands/instream habitat features that promote nutrient uptake and denitrification.

- A project must ensure that high functioning portions of the urban stream corridor are not used for in-stream stormwater treatment (i.e., where existing stream quality is still good).

- Stream restoration should be directed to areas of severe stream impairment, and the project should also consider the level of degradation, the restoration needs of the stream, and its potential functional uplift.

- Appropriate projects include those where it can be confirmed that one or more of the following impairments occur.

- Geomorphic evidence of active stream degradation (i.e., high BEHI score)
- An IBI of fair or worse
- Hydrologic evidence of floodplain disconnection
- Evidence of significant legacy sediments in the floodplain

In all cases, designers should consult in advance with state and federal regulatory agencies to get feedback on project suitability.

Many project qualifying conditions can be assessed using data routinely acquired for the design of any stream restoration project, such as:

- Stream geometry, planform and classification
- Stream and floodplain elevation survey
- Sewer and utility investigation
- Wetland delineation
- Forest stand delineation
- Aquatic life surveys
- Contributing watershed conditions
- Hydrologic and hydraulic modeling

2.1.3 Protocol-specific Testing for Credits

Most of the protocols require specific tests or site monitoring to support the credit calculations that need to be factored into project budgets. They are outlined in Table 4 and described in greater detail later in the section.

Table 4. Protocol-Specific Site Investigations

Protocol 1	**Protocol 2**
• Measuring Bank Retreat Rates • Project Efficiency Monitoring (optional) • Bulk Density and Sediment Nutrient Content	• Mapping EHZ (surveys) • Floodplain soil profiles • Groundwater monitoring (optional)
Protocol 3	**Protocol 5**
• Legacy Sediment Investigations • Hydrologic/hydraulic modeling • Wetland Delineation	• Vertical Incision • Channel Parameters • Bulk Density • Sediment Nutrient Content
Protocol 4 does not include any protocol-specific site investigations.	

2.1.3.1 Protocol 1 Site Assessments

Field Monitoring Options to Measure Bank Retreat

There are several traditional methods to monitor streambank erosion rates, most of which rely on fixed-station measurements to assess bank retreat over time.

BANCS Method: The original expert panel encouraged the use of the BANCS method to estimate bank erosion rate. More formally known as the Bank Assessment for Nonpoint Consequences of Sediment, the BANCS Method (Rosgen, 2001), is used to calculate BEHI and NBS scores, which in turn, are entered into regional bank erosion curves to determine the annual rate of streambank retreat. To date, the BANCS method is the most popular technique to measure bank retreat, but other methods are available.

The BANCS method utilizes two commonly used bank erodibility estimation tools to predict streambank erosion; the Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) methods. Each tool is susceptible to high variability when performed by different practitioners in the field.

BANCS assessments should be performed by teams of two qualified stream restoration practitioners in order to better calibrate their observations and obtain an average of their two assessments. Having more practitioners assess the project reach has been found to improve the accuracy and reduce uncertainty around the most sensitive BEHI and NBS parameters (Bingham et al 2018).

Particular care should be taken to accurately measure the study bank height, root depth, and bank angle, as these have been identified as the most sensitive BEHI parameters. Where possible, best practice is to measure bank height (and sometimes root depth) using survey equipment; bank angle can be measured using an inclinometer or pitch and angle locator.

To help practitioners standardize their assessments, the U.S. Fish and Wildlife Service has developed guidance on how to apply the BEHI and NBS tools that builds on previous work (Rosgen 2006, Rosgen 2008). The documents can be found in the Protocol 1 Technical Resources Box.

The extrapolation of monitoring data to unmeasured banks should be done with care and the monitored cross sections should be representative of those within the project reach.

All BANCS assessments should be conducted by qualified stream restoration professionals. While the group did not categorically define the term “qualified stream professional” – this decision should be made by the project owners/sponsors – it is recommended that they have received some formal BANCS training by a qualified instructor, such as the Rosgen Level 3 training, and have personally reviewed the site conditions.

The expert panel provided the Hickey Run curve as an example of a regional bank erosion curve, but it should be used with relative caution because limited data was used to construct it. In the meantime, in order to help provide more consistency among BANCS assessments, practitioners are recommended to use the spreadsheet in the Technical Resources Box that was developed using data from multiple stream sources including Hickey Run [3].

Bank Pin Monitoring: One of the most common methods for measuring sediment erosion is Bank Pin Monitoring. Bank pins are typically 4' smooth iron or steel pins driven horizontally into the bank to measure erosion rates based on the amount of the pin exposed over time. There is little standardized guidance on the use of bank pins, but several general principles should be adhered to (Gatto 1988):

- Pins are pushed perpendicularly into the face of the bank. The pin may be flush with the bank or left with a portion of the end of the pin exposed.
- Pin placement should be determined by the complexity of the bank and the needs of the project. Generally, at least 2 pins should be placed vertically on a bank at a given location to sufficiently capture the erosion rate.
- Measurements should be taken frequently to avoid loss of pins due to vandalism or a rapid erosion event. Following large rainfall events and frost events are recommended and monitoring should be done over a representative hydrologic period (e.g., minimum 3 years).

The number of bank pin monitoring sites along the reach may vary based on best professional judgement. It is recommended that pins be placed roughly every 200-500 linear feet based on the site-specific conditions in order to obtain a representative dataset.

Permanent Cross Sections: Permanent cross sections are cross sections that are repeatedly surveyed at the same location to determine changes in the stream channel. Typically, a permanent monument is fixed on each bank (left and right) and used to mark the starting location for future surveys.

Differential leveling surveys use an iron or steel pin to set the location of the permanent monument in each bank. Once the pins are installed, a Silvey Stake (or similar spring clamp) is placed on the outside of each pin so that when the tape is attached to the stake, the zero station is directly above the left pin. Once the tape is taut, the bank is surveyed using normal geomorphic survey procedures.

[3] Pennsylvania practitioners should follow PA DEP guidance regarding the BANCS method, found here.

Total station and survey-grade GPS surveys follow a similar procedure where the survey instrument measures a direct line to an established control point. The number of cross section sites along the reach may vary based on best professional judgement. It is recommended that cross sections be taken roughly every 200-500 linear feet based on the site-specific conditions in order to obtain a representative dataset. Cross-section surveys should also be performed over a representative hydrologic period (e.g., typically 3 years).

Bank Profiles: Bank profiles are surveyed using a vertical rod and tape. The rod is held vertical on a toe pin and horizontal measurements are made from the edge of the rod to the bank.

Alternative Remote Modeling Options to Measure Bank Retreat

There are several new modeling approaches available to stream restoration practitioners to re-construct 3-D images of the stream channel to measure bank retreat. While there are multiple approaches and software packages available, a brief description and general guidance is provided in this section.

Digital Elevation Model (DEM) Differencing

An approach gaining popularity with advances in digital imaging and drone technology is using DEM differencing to estimate bank erosion rates. There are a range of technologies available to obtain DEMs, including GPS, photogrammetry, airborne or terrestrial LiDAR, and structure from motion. Each technology has a range of applications and restrictions in terms of spatial and time scales when employed to obtain 3-D terrain data.

LiDAR is probably the most common of the technologies. It is a surveying method that measures distance to the stream bank by illuminating the bank with laser light and measuring the reflected light with a sensor. Differences in laser return times and wavelengths can then be used to make digital 3-D representations of the stream channel. New photogrammetry approaches, like structure from motion, can be used to help refine older LiDAR datasets and are converted to 3-D representations with relatively cost-effective software packages (James et al. 2019).

By taking LiDAR imagery at two different times in the same location, the 3-D images can be compared to measure the bank erosion over time. To calculate the prevented sediment erosion for Protocol 1, you should have at least five DEM datasets: two pre-restoration DEMs to determine the pre-restoration erosion rate; one immediately after restoration; one, one year after project completion; and then the final DEM three years after project completion.

There are several methods available for the use of DEM differencing to measure bank erosion. Software packages are used to complete the change detection, then uncertainty is estimated to help evaluate the results (Wheaten et al 2010). The choice of methodology will depend on the quality of the available data, data size, project accuracy requirements, available hardware and available software.

It should be noted that when relying on aerial imagery, banks can be obscured by a variety of natural and artificial features (i.e., trash, woody debris, vegetation, bank overhang, etc.) that affect the accuracy of the 3-D image. Therefore, some level of manual filtering may be needed to remove large unwanted features and to restrict the dataset to the exact areal extent of the study banks. However, removing vegetation from the survey data is difficult because roots, stems, and leaves blend into rougher parts of the bank topography (O'Neal and Pizzuto 2010).

Efficiency Factor Monitoring (optional)

The standard Protocol 1 nutrient and sediment removal efficiency rate is set at 50%, but can be increased if post-restoration bank retreat monitoring demonstrates that a higher value can be supported.

For an individual stream restoration project, the efficiency factor is defined as the monitored difference between pre- and post-project channel erosion rates. This can be determined by the same method used to measure the pre-project rate:

- BANCS Assessment
- Bank Pin Monitoring
- Permanent Cross-Sections
- Bank Profile Measurement
- Digital Elevation Model (DEM) Differencing

Post-restoration monitoring should be conducted for a minimum of 3 years following completion of the project before re-calculating the restoration efficiency. Once the new restoration efficiency is calculated, the stream restoration project may be re-reported, replacing the original record. The re-calculated efficiency is then back-dated to ensure that higher reductions are credited for all of the years after installation.

Whichever monitoring approach is used for pre-restoration assessment should be used in the post-restoration assessment. For example, using the BANCS method prior to restoration to determine initial credit, then comparing the predicted prevented sediment erosion to post-restoration LiDAR differencing assessments would not be an appropriate comparison for determining the efficiency factor.

If the BANCS method is used for the post-restoration assessment, it should be based on the same regional erosion rate curve as the pre-restoration assessment. If new curves are available at the time of the post-restoration assessment, these curves should be used and the pre-restoration BANCS assessment should be re-done using the new curves.

On-Site Collection of Bulk Density and Soil Nutrient Parameters

More rigorous on-site data collection is now required to support the prevented sediment calculations. Two of the most important parameters to sample on-site include soil bulk density and soil nutrient concentrations. The stream experts provided the following guidance on collecting these samples.

Bulk Density: Bulk density is the mass of soil for a given volume. It is used to measure compaction. For purposes of Protocol 1, a bulk density soil sample should be taken from each soil horizon present within the restoration reach and weighted according to the relative abundance of each horizon layer. The samples should be collected from undisturbed soils using a core and analyzed in the lab using undisturbed sampling methods. Take the average of those bulk density values to input into Equation 1. Locations should be selected using the following guidelines (additional details are provided in the Technical Resources Box):

- The number of samples taken along the reach may vary based on best professional judgement. It is recommended that one sample be collected every 200-500 linear feet to get a representative sample.
- If multiple samples are taken, they should alternate cross-sections, left and right bank. Samples should be taken from erosional areas where feasible.
- Samples should be collected from each soil horizon identified within the restoration reach. If one horizon is larger than others, more samples should be taken from that horizon to ensure the reach average is representative of bank conditions.
- Take samples from intact bank and not bank material that has fallen/slumped and is now depositional.
- Where unable to take a sample because of large rocky material, select another location
- If the sample is too gravelly to keep the core intact, the sample may need to be disregarded.

Sediment Nutrient Concentrations: Soil nutrient concentrations are highly variable from site to site. Therefore, soil samples from the project reach should be collected and analyzed for TN and TP concentrations. Samples should be taken from the same locations as the bulk density samples and analyzed using the following methods, or their equivalents:

- Total P concentration: Total-sorbed P – EPA Method 3051 + 6010 (USEPA 1986)

- Total N concentration: Total N combustion testing (Bremner 1996)

2.1.3.2 Protocol 2 Site Assessment Methods

Mapping the EHZ

The actual dimensions of the EHZ should be determined by site investigations to confirm that the intended water table elevations have been achieved.

Practitioners need to assess site factors to demarcate the EHZ across the valley bottom, such as hydric or saturated soils, presence of carbon sources and/or active root zones, or other floodplain stratigraphy that is less than 18 inches above the channel bed or low flow water elevations. These factors are used to accurately map the lateral EHZ boundaries at the project site, and can include:

- Trenches, direct push coring, observation of exposed stream banks, and/or tile probing analyses of exposed streambanks to document soil stratigraphy and identify buried floodplain soils, basal gravels, bedrock or groundwater elevations.

- Direct push coring provides similar information to trenches, but can cover more area with somewhat less precision.

- Tile probes can identify depths to gravel and bedrock over a larger area in less time, but are limited to "feel" rather than sight.

- Radiocarbon dating of organic material combined with magnetic resonance imaging can constrain the ages of floodplain stratigraphy and target restored floodplain elevations.

Methods should be tailored to reach conditions when defining the target elevations and boundaries for the project EHZ. Photogrammetric survey or LIDAR methods also may be used to create a digital elevation terrain model to assist in identifying the lateral boundaries of the EHZ.

Research indicates the importance of carbon availability for denitrification at the site. Pre- and post-restoration plans should ensure that extensive plant cover is established and dead wood recycled along the riparian corridor of the stream reach.

Geotechnical testing may be required to confirm the depth of hyporheic exchange. Areas of bedrock outcroppings or confining clay layers should be excluded and the dimensions of the EHZ adjusted accordingly.

2.1.3.3 Protocol 3 Site Assessment Methods

The following investigations are important for floodplain restoration projects:

1. *Verify the presence of legacy sediment deposits or other floodplain impairment*. The presence of legacy sediments should be confirmed by on-site investigations

of soil stratigraphy and other evidence that characterize stream valley bottom materials (e.g., such as buried hydric soils, woody material or leaf pack, etc.).

Other information that can corroborate legacy sediments includes land records, historical atlases and maps, past aerial photographs or current LIDAR measurements. Land Studies (2017) provides a good example of how historical research methods were used to define and interpret legacy sediments for a valley bottom restoration project in Brubaker Run, PA.

2. *Floodplain connection to valley bottom aquifer*. Field investigations may be needed to identify the current groundwater elevations relative to hydric soils, existing root zones and the stratigraphy of the floodplain. For effective root zone interaction, the streambed should be on or within the underlying hyporheic aquifer and the surface of the floodplain should not extend more than 18 inches above either the channel bed (in riffles) or residual pool water surface elevation (i.e., during minimal flow).

3. *Define boundaries for the channel(s), floodplain and valley bottom*. The restored channel and floodplain dimensions are based on field testing that define the key vertical and lateral sediment boundaries of the existing floodplain and the hyporheic aquifer beneath it. These boundaries can be measured by a combination of the following methods: direct push soil coring, trenching, test wells, LIDAR surveys, photogrammetry or other site investigations.

4. *Meet applicable floodplain management requirements in the stream corridor*. Any individual stream restoration project should be assessed with hydrologic and hydraulic models to demonstrate whether it increases water surface elevations or adverse downstream flooding impacts. In general, these analyses are based on design storm events and flood risk conditions established by the appropriate local or state floodplain management agency (e.g., the 100-year storm event).

5. *Floodplain wetland delineation:* Wetland delineations are normally required for most floodplain restoration projects. This data is used in Protocol 3 to define the wetland types (and corresponding removal rates) to apply to the FTZ. Wetland delineation should always be conducted by a qualified professional in accordance with the USACE 1987 Wetland Delineation Manual (USACE, 1987) and applicable Regional Supplements for all potential restoration or rehabilitation projects. The State of Pennsylvania has developed an excellent resource to use to define and delineate wetlands.

2.1.3.4 Protocol 5 Site Assessments

Protocol 5 requires different site measurements as it deals with vertical, rather than lateral erosion, in the headwater stream channel. The following dimensions need to be measured at the existing headwater channel:

- Length of Proposed Project Reach (ft)
- Channel Slope (ft/ft)
- Bank Height (ft)
- Bottom Width (ft)
- Top Width (ft)
- Bulk Density (lb/ft^3)

In addition, the bottom width needs to be measured at a comparable stable reference reach to support the equilibrium model. Table 5 provides a summary of the data needs to support a 3-D surface modeling analysis of the existing and proposed channels.

The channel slope, bank height and top and bottom width should be taken at three representative cross-sections within the project reach prior to construction. The average of the three cross sections will be used for the calculations. Bulk density samples should be taken roughly every 200 ft along the project reach. For sites shorter than 200 ft, one sample is sufficient.

In addition, Protocol 5 projects need to collect on-site soil bulk density and nutrient content samples, as specified for Protocol 1 projects.

Table 5. Summary of Information Needed for 3D Surface Analysis

	Parameter	*Source*
Pre-Restoration Channel	Length of Project Reach	Measured
	Average Bank Height	3 measured cross sections
	Average Bottom Width	3 measured cross sections
	Average Top Width	3 measured cross sections
	Base Level Controls	Fixed start and end points determined by bedrock, existing infrastructure or downstream confluence
Equilibrium Channel	Equilibrium Bed Slope	Equations in Table 1 of OGS Memo
	Equilibrium Bank Slope	1.76 : 1
	Average Bottom Width	3 measured cross-sections from reference reach

Section 2.2 Applying the Appropriate Protocols to Earn Credit

This section provides an updated summary of all five protocols that can be used to earn pollutant removal credit.

Protocol 1: Credit for Prevented Sediment during Storm Flow

Protocol 2: Credit for Instream and Riparian Hyporheic Nutrient Processing

Protocol 3: Credit for Floodplain Reconnection Volume

Protocol 4: Credit for Dry Channel RSC as an Upland Stormwater Retrofit

Protocol 5: Credit for Outfall and Gully Stabilization (OGS) Practices.

Each section begins with a "What's New Since 2014" Box and ends with a Technical Resources Box where practitioners can access useful technical resources to properly apply the protocols.

Some protocols are additive, and an individual stream restoration projects may qualify for credit under one or more of the protocols, depending on its design and overall restoration approach.

2.2.1 Updated Protocol 1: Prevented Sediment

The goal of the updated Protocol is to provide guidance to improve the replicability and accuracy of prevented sediment calculations.

What's New for Protocol 1
• New guidance on which categories of bank armoring are acceptable/not acceptable for crediting • On-site measurements of prevented sediment parameters now required (soil bulk density and nutrient content) • More guidance on field methods to estimate bank erosion rates • Incentives to perform project efficiency monitoring to earn higher credits

The protocol follows a basic four-step process to compute a mass reduction credit for prevented sediment:

1. Estimate stream sediment erosion rates and annual sediment loadings
2. Adjust project length to account for hard armoring practices
3. Convert erosion rates to nitrogen and phosphorus loadings, and
4. Estimate reduction attributed to restoration.

Step 1. Estimate the Stream Sediment Erosion Load

The measured (or BANCS-modeled) pre-restoration erosion rate for the project reach is entered into the following equation to determine its potential prevented sediment load.

Equation 1: $S = \Sigma(cAR) / 2{,}000$

where:

S = sediment load (ton/year) for reach or stream
c = measured bulk density of soil (lbs/ft^3)
R = bank erosion rate (ft/year)
A = eroding bank area (ft^2)
2,000 = conversion from pounds to tons

Step 2: Adjust Project Length to Account for Hard Armoring Practices

Designers should adjust their project reach length to account for bank armoring techniques that are defined as "non-creditable or "creditable with limits."

Table 6. Bank Armoring Practices with Restricted Credits

Non-Creditable Armoring	Creditable w/ Limits
• Concrete retaining walls • Gabions • Dumped rip-rap • Sheet piling/planking • Block walls • Geogrid/concrete/gabion mattresses • Non-biodegradable soil stabilization mats/systems	• Angular riprap stone installed for bank protection • Imbricated rip rap • Berm/pool cascades • Boulder revetments

These armoring designations affect the credit calculation in the following manner.

Non-Creditable Armoring Practices: These practices should not be used in any creditable stream restoration practice unless required for the protection of critical infrastructure. The length of the reach that utilized non-creditable armoring practice should be subtracted from the total reach length when determining sediment load reductions.

- Example: A stream restoration project with 1,000 ft of restored banks requires 50 ft of infrastructure protection. When using Protocol 1, the 50 ft of armored streambank should be excluded from the bank erosion estimate and only 950 ft of the reach are credited.

Creditable with Limits Armoring Practices: These practices are allowable, with full credit, on up to 30% of the restored banks (both sides). In constrained urban environments, there are often limited options for spreading out flow and reducing shear stress. To maintain stable stream banks in these environments, limited armoring may be needed. Application of these techniques should be limited to outer meander bends and areas of high shear stress where additional protection is required to stabilize the banks. Any bank length armored by a practice in this category that exceeds the 30% limit is proportionally subtracted from the total sediment load reduction.

- Example: A stream restoration with 1,000 ft of restored banks includes 400 ft of imbricated rip rap. This exceeds the 30% limit by 100 ft, or 10% of the total bank length. Therefore, if the project earned 200 lbs of reduction using Protocol 1, you may only claim 180 lbs.

Step 3. Convert Streambank Erosion to Nutrient Loading

To estimate nutrient loading rates, the prevented sediment loading rates are multiplied by the average measured TP and TN concentrations in the streambank sediment.

Step 4. Estimate Stream Restoration Efficiency

Streambank erosion is estimated in Step 1, but not the efficiency of stream restoration practices in preventing bank erosion. An efficiency factor should be applied to account for the fact that projects will not be 100% effective in preventing streambank erosion and that some sediment transport occurs naturally in a stable stream channel.

While the stream experts concluded that a baseline 50% reduction was conservative, they felt it was still an appropriate starting point that would incentivize more site-specific monitoring for prevented sediment. Efficiencies greater than 50% are allowed for monitored projects that have shown a higher rate can be justified (see Section 2.1.3.1).

TECHNICAL RESOURCES INDEX FOR PROTOCOL 1
Protocol 1 Design Example Spreadsheet Tool for Erosion Rate Estimates Bulk Density and Soil Nutrient Concentration Methods Guidance BEHI Protocol Guidance NBS Protocol Guidance

Bank Protection Practice Descriptions

Computing Streambank Erosion Rates Memo

Four Step Method for Using CAST to Determine Sediment Delivery

Derivation of Protocol 1 (Historic) from 2014 Expert Panel Report

2.2.2 Updated Protocol 2: Hyporheic Denitrification

This protocol applies to stream restoration projects where in-stream design features are incorporated to promote denitrification by improving exchange between the hyporheic exchange between the stream channel and the floodplain rooting zone. Qualifying projects can stack this credit with Protocols 1 and 3 and use this protocol to determine enhanced nitrogen removal through denitrification within the stream channel during base flow conditions.

What's New for Protocol 2
For All FR Projects: ● The old Hyporheic Box was replaced with an area-based "Effective Hyporheic Zone". The lateral dimensions of the EHZ are defined by locations where the restored floodplain elevations are less than 18 inches above the low flow water elevations and confirmed through on-site soil/groundwater investigation ● New definition for how the lateral boundaries of the EHZ should be measured in the field and shown on post-construction plans. ● The denitrification rate (1.95 x 10 $^{-4}$ lbs/ton/day) was replaced with a new rate (2.69 x 10^{-3} lbs NO_3/sq ft/year) based on the latest science. The rate will now also be adjusted based on site factors, such as seasonal streamflow, floodplain soil saturation and the underlying materials in the hyporheic aquifer (i.e., the Parola Equation). ● The bank height ratio (≤1) requirement was eliminated, since these don't typically apply to most low-bank FR projects. ● Final nitrogen reduction should reflect the difference between pre- and post-restoration conditions.

Step 1. Define the Extent of the EHZ.

Calculate the EHZ area of the restored floodplain and channel, separately.

- The floodplain area eligible for P-2 credit includes the region below and alongside a stream where there is an exchange and mixing of shallow groundwater and the surface water in the channel. This region corresponds with the lateral extent of a hyporheic aquifer composed of a porous medium, typically gravel, sand or fractured/degraded bedrock.

- The hyporheic aquifer also includes a thin layer of floodplain soils above this base layer and is encompassed with in the hyporheic exchange zone (HEZ). Increasing the geomorphic complexity of the stream/floodplain system promotes greater surface water/shallow groundwater interaction throughout the EHZ and should be encouraged. This complexity can involve increasing channel sinuosity, creating multi-thread channels, and installing instream wood and riffle structures to reduce flow velocities and increase in-stream transient storage.

- Operationally, the EHZ extends laterally across all areas of the channel and floodplains that are less than 18 inches above the channel bed or low flow water elevations. Any area of high floodplain (i.e., elevation greater than 18 inches above channel bed or low flow water elevation) are excluded from any P-2 credit.

- The 18-inch floodplain elevation is a nutrient crediting-based threshold and represents the typical root zone that facilitates hyporheic exchange and provides a carbon source for denitrification. Most of the root mass is within 12 inches of the ground surface but may extend to 18 inches (National Research Council, 1995). The experimental values for rates of denitrification have come from saturated zones within 18 inches of the surface.

Step 2. Apply the Denitrification Rate to the EHZ

Base Denitrification Rate: Since the original expert panel report was published, several new studies have reviewed nitrogen removal rates in restored streams. The new areal denitrification rate is:

1.49 mg $NO_3/m^2/hr$ or 2.69×10^{-3} lbs NO_3/sq ft of EHZ /year.

The new rate is based on the difference in median nitrate uptake rate between restored and unrestored streams from Newcomer-Johnson et al. (2016) -- 4.96 mg $NO_3/m^2/hr$. The rate was then adjusted to assume that 30% of this uptake is from denitrification based on data on urban streams from Mulholland et al. (2008).[4]

The new rate combines the most up to date, comprehensive review of nitrate uptake literature, with the most comprehensive denitrification study to produce a defensible rate. Furthermore, this areal denitrification rate provides a more relevant metric for calculating nitrogen removal based on the area of the EHZ.

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[4] Calculation for the final areal denitrification rate: 1.8-0.42 = 1.38 µg/m^2/s = 4.96 mg $NO_3/m^2/hr$ (from Newcomer Johnson et al. 2016). 4.96 x 0.3 = 1.488 mg $NO_3/m^2/hr$ (from Mulholland et al. 2008).

Step 3. Apply the Site-Specific Discount Factors to Adjust the Base Denitrification Rate

Site-specific factors are an important influence on denitrification capacity within the reconnected floodplain. Parola et al. (2019) developed a simple equation to adjust the base denitrification rate to account for these site-specific factors, which is shown in Table 7. Guidance is also provided on how to estimate reduction factors for baseflow, floodplain height and aquifer conductivity at individual sites.

Table 7. Site Specific Discount Factors for Adjusting the Denitrification Rate (Parola et al, 2019)

Effective Hyporheic Zone N credit = (Base Rate) (EHZ) (B_f) (H_f) (A_f)

Baseflow Reduction Factor (B_f)		Floodplain Height Factor [1] (H_f)		Aquifer Conductivity Reduction Factor [2] (A_f)	
Perennial baseflow	1.0	0-0.75 ft	1.0	cobbly gravel, gravel, gravelly sand, sand and peat	1.0
Baseflow in all but late summer/fall	0.75	0.76 ft – 1.00 ft	0.75	gravelly silt, silty sand, or loamy sand, sandy loam, and organic silt with no coarse material layer connected to the streambed	0.60
Baseflow in winter/spring	0.50	1.01 ft – 1.25 ft	0.50	clayey gravel, sandy silt, or sandy clay loam, loam, silt loam, and silt with no coarse material layer connected to the streambed	0.40
Baseflow only during wet seasons	0.25	1.26 ft – 1.50 ft	0.10	sandy clay, clay loam, silty clay loam, organic clay with no coarse material layer connected to the streambed	0.10
Flow only during runoff events	0.10	>1.50 ft	0.00	silty clay and clay with no coarse material layer connected to the streambed	0.01

[1] The floodplain height factor is determined by the restored floodplain height (Hf) above the streambed riffle elevations or low flow water surface elevations. Additional streambed feature elevations, like those at a run in sand bed channels or streambeds comprised of silty clay, also may be used to determine the restored floodplain height. Low base-flow (lowest 10% of flows) could also be used as a suitable alternative.

[2] This refers to an aquifer capacity factor based on the dominant materials within the streambed and below the floodplain soil of the EHZ. Where coarse grain aquifer layers are not directly connected to the channel, the factor should be determined based on the soil texture at the elevation of the streambed using NRCS standard texture classifications (Schoeneberger, et al., 2012).

"Base Rate" is the mean areal floodplain denitrification rate (lbs/sq foot/yr), as recommended by Group 4.

The first factor relates to the soil texture in the hyporheic aquifer beneath the proposed EHZ. In general, groundwater movement is enhanced by direct hydraulic connection with a coarse grain layer or peat layer that extends beneath the floodplain. While channels without direct hydraulic connection to an underlaying coarse grain material layer can still be credited, surface water/groundwater exchange is more constrained when the aquifer is composed of tighter silts and clays (which were often deposited in the legacy sediment layer). Under most low gradient conditions the residence time in clean gravels and sands is sufficient for denitrification (6-12 hours), and additional residence time would not further enhance denitrification.

Strict use of soil lateral conductivity would lead to extremely low rates of lateral transfer of hyporheic water through silt and silty soils and would not reflect the importance of the cycling of root biomass and root architecture for establishing preferential flow paths and enhancing lateral hydraulic conductivity (Ghestem et al., 2011; Lu et al., 2020; Newman et al., 2004; Noguchi et al., 1997; Wang et al., 2020). Therefore, the aquifer conductivity reduction factor is based on the relative differences in material hydraulic conductivity between soil types (Domenico and Schwartz, 1990), adjusted to account for the impact of root mass.

The second factor, floodplain height, is based on the importance of sustained saturated soil in the rootzone. Prolonged soil saturation creates anaerobic conditions important for denitrification (Martens, 2005). One way to estimate groundwater elevations in the floodplain is to use the height of the riffle crest profile, or low baseflow (lowest 10% of flow) elevation. If the groundwater table remains within 9” of the floodplain for most of the year, it is an indicator that the ideal conditions for denitrification are present across the extent of the EHZ.

The last factor includes the seasonality of streamflow within the hyporheic zone, which varies depending where the reach is located in the stream network. The reduction factors are based on the proportion of the year in which baseflow is present. The importance of valley slope was also considered as a factor but was excluded to avoid further complication.

Step 4. Calculate the Total Nitrate Removed

TECHNICAL RESOURCES INDEX FOR PROTOCOL 2
Protocol 2 Design Example Derivation of Protocol 2 (Historic) from EPR Hyporheic Denitrification Science

2.2.3 Updated Protocol 3: Floodplain Pollutant Trapping

This protocol provides an annual mass sediment and nutrient reduction credit for qualifying projects that reconnect stream channels to their floodplain over a wide range of storm events, from the small, high frequency events to the larger, less frequent events. Qualifying projects can stack this credit with Protocols 1 and 2 (if applicable) and use this protocol to determine enhanced sediment and nutrient removal through floodplain wetland connection.

This method assumes that sediment, nitrogen and phosphorus removal occur only for that volume of annual flow that is effectively in contact with the floodplain during storm events. Some variability in the results of Protocol 3 can be expected depending on which hydrologic model is used for estimating floodplain connection volume. Project-specific calculations should be used when design details are available. Note that, similar to Protocol 2, the load reduction is the difference between the "existing" and "design" FP trapping at the project site.

What' s New for Protocol 3
For All FR Projects: ● Need to define the vertical and lateral dimensions of the floodplain trapping zone (FTZ) to reflect a project's increased floodplain reconnection. ● Replaced the "upstream" method of using rainfall-runoff models to determine the amount of stream flow that is diverted into the floodplain, with a "downstream" method that uses scaled, representative USGS gauge stations to calculate overbank flow. ● Applied updated annual nutrient and sediment removal rates to the pollutant loads in streamflow that accesses the FTZ. The new rates reflect the latest science from recent expert panel reports that investigated pollutant removal by non-tidal wetland restoration projects, and is based on the predominant floodplain wetland conditions ● The upstream watershed to floodplain surface area ratio reduction was removed. ● Nutrient and sediment reductions are only applied to overbank flow. ● CAST is used to estimate the final load reduction

Step 1. Determine the treatment depth in the FTZ

On-site data are needed to establish channel flow and floodplain capacity and define the future boundaries of the floodplain trapping zone. These methods can include spatial data from field-run topographic field surveys, LIDAR data or drone surveys. The data helps delineate the above-ground FTZ volume and boundaries within the project reach, along with modeled hydraulic parameters such as critical shear stress velocities.

The 2014 expert panel established a one-foot floodplain elevation cap for crediting purposes, based on the assumption that suspended sediments more than a foot above the floodplain surface would not settle out onto the floodplain. Newer research recommends replacing the one-foot elevation cap with a variable cap based on critical floodplain velocities. The group recommends that the upper limit of the floodplain trapping zone be defined by floodplain elevations that remain below critical floodplain velocities, as defined by 1-D HEC-RAS or 2-D hydrodynamic models [5] .

The one-foot elevation cap remains as a default, but can be higher when modeled floodplain flow velocities are below 2 ft/sec (up to 3 feet or the 10-year water surface elevation, whichever is lower). Hydraulic modeling should assume a Manning's n roughness on the floodplain of 0.07 and in the stream channel of 0.035. Coleman and Altland (2020) provide more guidance on defining the maximum FTZ elevation. The new methods can be used for most projects and is provided in the Technical Resources Box, but see Section 3.8 for some MD-specific guidance on the floodplain ponding issue.

Step 2. Identify the channel flow, floodplain flow at the treatment depth in the FTZ, and mean baseflow

The downstream approach estimates the floodplain diversion volume using stream flow data derived from USGS 15-minute interval flow gages that have similar watershed characteristics as the project site being evaluated.

The range of flow statistics are then related to the channel capacity of the project reach to compute the estimated overflow frequency and volume to the floodplain, given its new channel/floodplain dimensions. Several methods have been explored by Altland et al (2019), Doll et al (2018) and Lowe (2016).

Each downstream method uses flow duration curves, hydrograph separation and other flow processing techniques to define a range of flow conditions using USGS gage data.

The key flow conditions include: baseflow (50% recurrence interval), channel flow, treatable floodplain flows (w/in one foot of floodplain invert) and untreatable floodplain flows (that are more than the one-foot default elevation cap or higher elevation cap depending on modeled floodplain flow velocities).

Step 3: Develop an appropriate flow duration curve from comparable USGS gauge station.

Practitioners have the flexibility to develop their own downstream flow diversion models, but should use the following to ensure consistency:

- USGS gauge data with minimum 15-minute time step
- USGS gauge data with 10+ year flow record
- USGS gauge from watershed in the same physiographic region with similar land cover, slope, and percent karst
- USGS gauge data scaled by comparing the drainage area of gauge site to project site drainage area

[5] Maryland practitioners should follow guidance from MDE, found here.

Step 4. Determine the treatable flow

This step is used to estimate the potential additional runoff volume that can be diverted from the stream to the floodplain during storm events. Credit for this protocol applies only to the additional runoff volume diverted to the floodplain beyond what existed prior to restoration. Designers conduct detailed hydrologic and hydraulic modeling of the subwatershed, stream and floodplain to estimate the potential floodplain connection volume.

HEC-RAS or a similar model are used to determine the channel flow (the flow that would just fill the existing channel without overtopping its banks) and the floodplain flow at maximum creditable floodplain inundation depth (1 ft is the default unless modeling shows velocities below the threshold described previously).

Step 5. Determine the load delivered to the project site.

The unique sediment and nutrient pollutant loads delivered from the upstream contributing drainage area to the project reach can be quickly determined using the CAST. This tool, which replicates the geographically unique pollutant loads of the Chesapeake Bay Watershed Model, can be accessed from the Technical Resources box, or directly from https://cast.chesapeakebay.net/streamcalculator.

Step 6. Apply the appropriate floodplain wetland pollutant removal rate

The original expert panel report reasoned that floodplain pollutant removal from overbank flow would behave in the same fashion as a restored floodplain wetland (Jordan, 2007). Therefore, the pollutant load treated by the floodplain was multiplied by a base wetland removal rate. Since then, two new expert panels have reviewed the pollutant removal capability of non-tidal wetland restoration practices (WEP 2016; NTW EP 2019). The expanded data analyses provide a stronger technical foundation to support base wetland removal rates for the floodplain trapping zone. The removal rates established for three different categories of non-tidal wetland “restoration” are shown in Table 8.

Table 8. Floodplain Wetland Removal Rates in Prior CBP Expert Panel Reports

Wetland BMP Category	Pollutant Removal Rate (compared to pre-restoration)		
	Total N	Total P	TSS
NTW Restoration	42%	40%	31%
NTW Creation	30%	33%	27%
NTW Rehabilitation	16%	22%	19%

[1] as outlined in expanded lit review and recently approved Expert Panel Report (NTW EP, 2020)
[2] rates are applied to the stream bed and bank load delivered to the project reach. The “upland acres treated” factors from the NTW EP do not apply for Protocol 3.

The pollutant removal rate applied to the floodplain treatment volume should reflect the predominant floodplain wetland category(s) present at the site, as defined in Table 9.

Any wetlands that fall within the boundaries of the FTZ and are reported for credit under Protocol 3 should not also be reported using the Non-Tidal Wetlands Expert Panel, as it would double-count nutrient and sediment reductions from these practices.

Wetland delineations are normally required as part of the stream restoration permit approval process. Consequently, designers should have adequate field delineation data to determine how much project floodplain area falls into each restoration category and choose the correct rate to calculate pollutant removal within its FTZ.

Table 9. Definitions of Restoration Categories from NTW EP (2020)

Restoration: Manipulate physical, and biologic characteristics of a site with the goal of returning natural/historic functions to a former wetland:

- No wetland currently exists or has been extensively degraded
- Hydric soils are present
- "prior converted"

Creation: Manipulate site characteristics to develop a new wetland that did not previously exist at the site:

- No wetland currently exists
- Hydric soils are not present
- Functional gain due to new wetland features

Rehabilitation: Manipulate site characteristics with the goal of repairing natural/historic functions to a degraded wetland:

- Wetland present
- Wetland condition or function is degraded

TECHNICAL RESOURCES INDEX FOR PROTOCOL 3

Protocol 3 Design Example

Restored Floodplain Velocity Case Study Analysis

Developing Regional Flow Duration Curves for Protocol 3

Non-Tidal Wetland Expert Panel Report

Derivation of Protocol 3 (Historic) from EPR

2.2.4 Protocol 4 Dry Channel RSC as a Stormwater Retrofit

Because the Panel decided to classify dry channel RSC systems as an upland stormwater retrofit, designers should use the protocols developed by the Urban Stormwater Retrofit Expert Panel to derive their specific nutrient and sediment removal rates (WQGIT, 2012).

That Panel developed adjustor curves to determine TP, TN and TSS removal rates based on the depth of rainfall captured over the contributing impervious area treated by an individual retrofit. In general, dry channel RSCs should be considered retrofit facilities, and the runoff reduction (RR) credit from the appropriate retrofit removal adjustor curve may be used to determine project removal rates. The final removal rate is then applied to the entire drainage area to the dry channel RSC project.

Step 1. Determine CDA conditions: Estimate the upland drainage area and impervious cover contributing to the RSC project

Step 2. Calculate RSC Retrofit Storage; Estimate the volume of retrofit storage associated with the RSC project (in acre feet)

Step 3. Enter it into the Standard Retrofit Equation- Determine the number of inches that the retrofit will treat in the catchment

$$\frac{(RS)(12)}{IA} = x\ in \qquad \text{(Eq. 1)}$$

Where: RS = retrofit storage in acre-feet
12 = conversion from feet to inches
I = impervious cover percent expressed as a decimal
A = drainage area in acres

Step 4. Use the Adjustor Curves to Determine Site Removal Rates: Since RSC is classified as a runoff reduction (RR) practice, the RR removal curves are used, to define the sediment and nutrient removal rates for the retrofit

Step 5. Calculate Site Load Reduction: Apply the pollutant removal rates to the load generated from its upland contributing area, using CAST loading rates.

TECHNICAL RESOURCES INDEX FOR PROTOCOL 4
Protocol 4 Design Example Stormwater Retrofit EPR

2.2.5 Protocol 5 Alternative Prevented Sediment for Outfalls

This protocol, originally developed by MDOT SHA, uses a 5-step process to define the equilibrium headwater channel condition as a means of estimating prevented sediment loss from outfall and gully stabilization projects (MDOT SHA 2018). The alternate SHA protocol is based on the assumptions that bed and bank incision will cease once the channel reaches equilibrium slope and bank angle based on physical characteristics of the soil material. This approach accounts for sediment loss through vertical incision that is common at stormwater outfalls, but is not fully captured by Protocol 1.

The group developed the following process for practitioners in other Bay states. The simplified process involves 5-steps, as follows:

1. Define the Existing Channel Conditions
2. Define the Equilibrium Channel Conditions
3. Calculate Total Volume of Prevented Sediment Erosion
4. Convert Total Sediment Volume to Annual Prevented Sediment Load
5. Determine Annual Prevented Nutrient Loads

It is recommended that practitioners in Maryland continue to use the more detailed MDOT SHA alternate method to perform their computations.

Step 1: Define the Existing Channel Conditions

The following measurements need to be collected from the existing headwater channel:

- Length of Proposed Project Reach (ft)
- Channel Slope (ft/ft)
- Bank Height (ft)
- Bottom Width (ft)
- Top Width (ft)
- Bulk Density (lb/ft^3)

Step 2: Define the Equilibrium Channel Conditions

There are four components of an equilibrium channel that must be defined:

- Base Level Control
- Equilibrium Bed Slope (ft/ft)
- Equilibrium Bank Slope (ft/ft)
- Future Channel Width (ft)

Base Level Control:

Base level controls are the site constraints that bound the upstream and downstream extent of the equilibrium channel design and define the maximum extent of vertical scour at the project site in the absence of stabilization. Determine if the prospective project reach contains any of the following base level controls:

- Hard Point Control (ex. bedrock or existing infrastructure)
- Confluence (elevation of larger, stable, receiving stream)
- Channel at equilibrium (existing slope is within 5% of the equilibrium slope)
- Upstream Limit of Erosion (pipe outfall or other defining infrastructure)
- Downstream limits of equilibrium slope must be set at the downstream limits of project bed stabilization features

The upstream limit of the credit calculation method may not always be defined by a pipe outfall or defining infrastructure. Migrating knickpoints caused by the breach of mill dams (Merritts et al. 2013) are an example of a vertical erosion force where a pipe outfall may not be the defining upstream limit. If no pipe outfall or other defining infrastructure is present upstream of the restoration site, the upstream limit is determined by the equation:

$$L_{max}=153A_d^{0.6}$$

Where L_{max} is the maximum upstream channel length (ft) from a given point, and A_d is the drainage area (acres). Upstream limits of erosion should be field verified.

Equilibrium Bed Slope:

To calculate the equilibrium bed slope, use the equation(s) in Table 10 for the applicable bed conditions at the project site. The equilibrium slope analysis is based on methods from Technical Supplement 14B (TS14B)— Scour Calculations—of Part 654 of the National Engineering Handbook—Stream Restoration Design (Natural Resource Conservation Service (NRCS), 2007).

Table 10. Equilibrium Bed Slope Equations

Cohesive Bed	$S_{eq} = 0.0028A^{-0.33}$
Sand and Fine Gravel (0.1-5mm particle size)	$S_{eq}= 0.06 / (y * 62.43)$
Beds Coarser than Sand (>5mm particle size)	Average of 4 Equations Details can be found in 2.1.3 of Appendix A.
S_{eq} is equilibrium slope (m/m or ft/ft), A is drainage area (km^2), and y is mean flow depth (ft). When estimating the critical shear stress, a 10-year recurrence interval can be used for the design discharge, and intermediate suspended sediment concentration (1,000 to 2,000 ppm) can be assumed.	

Equilibrium Bank Slope

The equilibrium bank slope for this analysis has been defined as 1.76:1. According to methods from Technical Supplement 14A (NRCS 2007), it has been shown that equilibrium bank slopes range from 1.4:1 to 2.1:1 in the absence of the influence of seepage. Utilizing the equilibrium bank slope for medium dense sand of 1.76:1 provides a conservative estimate for this analysis.

Future Bottom Width:

Select a representative reach within the study reach (from the groundwater origin or outfall location to the selected base level control feature) and take the average of three reference cross sections. This average will represent the future bottom width.

Step 3: Calculate the Total Prevented Sediment

To calculate the total volume of prevented sediment, you must take the difference between the equilibrium channel condition and the existing channel condition. This can be done using 3D surface modeling programs, such as *InRoads* or *Geopak*.

Three-dimensional surface modeling can be a time and labor-intensive process. To aid local municipalities with initial site evaluation and project screening. Appendix C of the OGS report provides examples of good candidate sites for outfall restoration. Example calculations are also provided for select sites. Following a preliminary site inspection, municipalities can decide whether to pursue additional data collection and analysis.

Step 4: Convert the Total Sediment Volume to Annual Prevented Sediment Load

To convert the total volume of prevented sediment erosion to an annual timescale, divide the total volume by 30. Thirty years is recommended as a conservative estimate of the amount of time it would take an eroding outfall channel to export the total volume of sediment calculated in Step 3.

The mass load reductions should then be discounted to account for the fact that projects will not be 100% effective in preventing bed and bank erosion and that some sediment transport occurs naturally in a stable stream channel.

Consequently, a conservative approach assumes that projects will be 50% effective in reducing sediment and nutrients from the channel reach. Efficiencies greater than 50% should be allowed for projects that have shown through monitoring that the higher rates can be justified subject to approval by the states. This conservative factor should be multiplied by the annual prevented sediment load.

$$S_p = 0.5\ (S_v / 30)$$

Where S_p represents the annual volume of prevented sediment and S_v represents the total volume of prevented sediment calculated in Step 3.

The annual volume of prevented sediment must also be adjusted by the bulk density of the soil to determine the final annual prevented sediment load. Bulk density measurements can be highly variable and each project site should have one sample collected every 200 ft throughout the reach to determine a representative bulk density value. The NRCS Soil Series data (NRCS 2019) may be used to provide an estimate value for preliminary calculations. Multiply the annualized sediment volume by the bulk density to determine the annual prevented sediment load.

Some more detail on OGS practice applications can be found in the example projects provided in the Technical Resource Box.

Step 5: Determine the Annual Prevented Nutrients

Pollutant load reduction credits are awarded based on the amount of pollutant—TN, TP, and sediment—reduction estimated to occur as a result of the proposed project. The amount of TN and TP present along a project reach is determined by applying measured TN and TP concentrations to the annual sediment loading rate.

TECHNICAL RESOURCES INDEX FOR PROTOCOL 5
Protocol 5 Design Example Protocol 5 FAQ Document (Lowe, 2020) Example OGS Projects (MDOT SHA) OGS Site Screening Appendix

Section 2.3 Project Construction

2.3.1 Best Practices During Project Construction

The stream experts recommended a series of best practices during project construction to reduce the potential for unintended consequences associated with stream restoration projects, which include:

1. Reduce the use of "iron-stone" rock or sand and other iron-rich construction materials when raising the streambed to avoid iron flocculation during anoxia.

2. Decrease the use of labile organic matter added to the stream bed (e.g., compost) to avoid mobilization of metals or phosphorus.

3. If required by the appropriate federal, state or local regulatory authority, minimize removal of mature trees in the existing riparian zone, as specified in the project's forest conservation plan.

4. Minimize disturbance caused by construction access and use appropriate equipment to reduce compaction of the stream's bed, banks and floodplain.

5. Work "in the dry" during project construction to reduce potential for downstream bed sedimentation or turbid discharges.

6. Recycle wood from any trees cleared during construction to introduce carbon sources and restore habitat features within the restoration project site.

2.3.2 Standards for Post-Construction Project Documentation

Better project documentation is essential to support future verification efforts for stream restoration practices. In general, project sponsors usually require one of four kinds of construction documentation, depending on the era in which the project was constructed:

1. *Design Drawings:* projects without any sort of "as-built" or other construction documentation rely on original design drawings.

2. *"Red line":* Copy of design plans w/ info pertaining to installation of actual work documented by the contractor, engineer, third party or some combination thereof.

3. *Professionally surveyed as-built:* Surveyor conducts a topographic survey for the completed project, tied to the original design datum

4. *Project monitoring plan:* a narrative plan that guide post-construction monitoring activity at individual restoration projects before and after its permit expires.

The original expert panel outlined some minimum record-keeping requirements for stream restoration projects. The installing agency needs to maintain a project file for each project and maintain it for the lifetime for which the load reduction will be claimed. The stream experts recommended higher industry standards for post-construction plans and documents to support more rapid and cost-effective verification inspections in the future. Specifically:

- The design objective(s) for each stream restoration project should be clearly and concisely referenced in project construction documents. This information provides future inspectors with a better sense of the goals and objectives that the project was intended to solve (especially when they are numeric or quantitative).

- Designers and owners should retain data on the original project design that can assist in future forensic investigations. Some examples might include BANCS data such as BEHI/NBS scores, channel plans, cross-section and profile views, and any groundwater or well data collected as part of the initial project assessment.

- Project documentation should indicate how future vegetation will be managed within the project limits to promote enhanced forest cover where appropriate, while allowing for vegetation management to ensure stability of the restored channel over time. In areas that trees could compromise safety or infrastructure, the project documentation should indicate improved vegetative cover through the appropriate vegetation type.

- Post-construction documents should identify fixed photo stations or cross-sections along the project reach to determine future sediment stability. If possible, specific control sections should be monumented at reach locations that are most vulnerable to erosion and high shear stress.

- Depending on the project design, all post-construction plans should clearly demarcate the following features:

    - Locations and extent of the restored banks and riffles

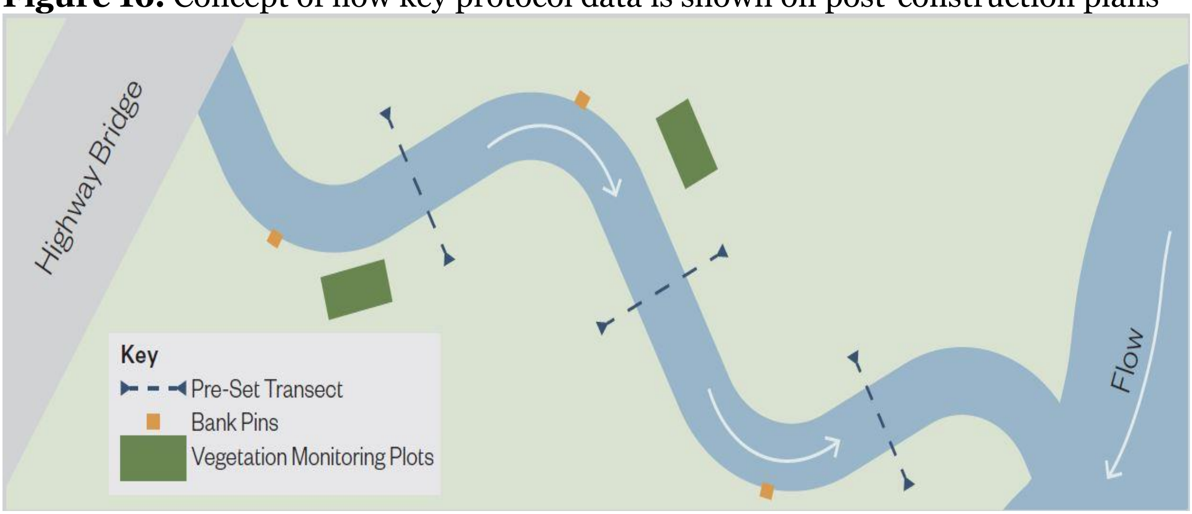
    - Design limits of the EHZ and FTZ, where used

    - Locations and elevations for bank height measurement stations

    - Any other locations for bank pins, random checks of floodplain or hyporheic zone, or vegetative cover plots needed to evaluate the project (Figure 16)

- While it is desirable to focus on fixed sections, failure can occur at any point along a project reach. Consequently, it is important to inspect the entire project reach during this rapid stream assessment. Geo-referenced digital photos should be taken at all areas where problems are observed or suspected.

Figure 16. Concept of how key protocol data is shown on post-construction plans



Section 2.4 Post-Construction and Project Verification

2.4.1 Guidelines for Inspecting and Verifying Individual Projects

The background on why BMP verification is important and how it applies to stream restoration projects is described in detail in Chapter 3.

This section describes the objectives for practice verification and then outlines the specific field and office methods that practitioners use to determine whether an individual project passes or fails.

The objectives of the new verification methods are to:

- Provide useful data to inform the design and increase the longevity of future stream restoration projects so that we can learn from our mistakes and reinforce our successes.
- Provide managers with data on how to adaptively manage future stream restoration projects to achieve more reliable pollutant reduction and ecosystem services.
- Impose reasonable and predictable costs for project sponsors that are consistent with those used to verify other urban BMPs.

2.4.2 Field Methods for Practice Verification

The field methods are intended to be simple, rapid, and repeatable. Their key elements are described below:

Stream restoration projects are dynamic over time. Changes in upland flows and sediment loads may cause some design elements within the project reach to adjust or even become compromised over time. These minor changes do not necessarily mean, however, that the entire water quality benefit is lost. Indeed, urban streams experience some “natural” rate of movement, which varies based on the type of stream, its physiographic region, intensity of past watershed development and presence of any legacy sediments. The existing crediting protocols were intentionally designed to be conservative to reflect a certain amount of project adjustment over time.

Focus on the dominant protocol in the project reach. If more than one crediting protocol is used on a project, the protocol that provides the greatest contribution to overall nutrient reduction in the project reach should be the major focus, (although more than one protocol may be needed in more complex projects).

A two-stage inspection process is utilized. The first stage involves a rapid inspection of the project reach to assess BMP condition. Projects are graded on a pass/action needed/fail basis. The guiding rule is that inspectors are looking for significant departures from its original design that may be compromising pollutant reduction function. Should a project appear to fail, a second forensic inspection is undertaken to diagnose the nature and cause(s) of the problem, and whether project functions can be recovered by additional work.

Trained field technicians rely on simple indicators along the reach to rapidly assess project function in the first stage.

In most cases, the field technicians take geo-referenced photos to document problems for quality control purposes. In general, the field technicians will take channel or bank measurements as needed, with locations based on field judgement, plan review or at any pre-selected control stations or monumented cross-sections shown on the plans

Look for fatal project flaws: Should a potentially fatal project flaw be discovered during any inspection log, the field technicians should document it with geo-referenced photos and share them with a more experienced stream assessor. A fatal flaw is defined as a systematic problem that does not trigger failure now, but could potentially compromise the entire reach in the near future. If the stream assessor concurs that the reach appears to be compromised or contains a fatal flaw, they can return to the site to conduct a second, more in-depth forensic inspection to determine what additional work may be needed.

2.4.3 Visual Indicators to Assess Performance of Stream Projects

The list of protocol-specific indicators is relatively short and emphasizes conditions that are easy to observe (e.g., exposed earth on banks, deep channel incision, etc.) and can be consistently interpreted in the field. The rapid inspection looks for any potential loss of pollutant reduction function in some or all of the project reach. The list of visual indicators is outlined in Tables 11 to 13.

Table 11. Defining Loss of P-1 Pollutant Reduction Function for Protocol 1 Projects (Prevented Sediment)	
Criteria for Loss	**Key Visual Indicators**
Evidence of bank or bed instability such that the project delivers more sediment downstream than designed, as defined by exposed soils/fresh rootlets	• Bank erosion (e.g., exposed bare earth or undercutting bank) • Departure of more than 20% from average post-construction design bank height[1] • Incised channel, as indicated by loss of defined pools and riffles and/or presence of an active head cut • Flanking or scour of in-channel structures • Failure or collapse of allowable bank protection practices • Less than 80% ground or canopy cover in the restoration zone[2]
[1] as measured at riffles from the project as-built drawing, preferably from pre-designated control sections established at its most vulnerable locations [2] depending on the long-term vegetative community objectives established for the project, may be expressed as a measure of exposed surface soil (>20%) or canopy cover (<80%)	

Table 12. Defining Loss of P-2 Pollutant Reduction Function for FR Projects (Denitrification in the EHZ) [1]	
Criteria	*Key Visual Indicators for FR Projects*
Evidence that the reach does not meet the design assumptions for the EHZ (such as when channel incision reduces access to hyporheic zone).	• Less than 80% of ground or canopy cover established in the project's EHZ • Stream lacks any observable baseflow during normal dry weather conditions • Bank height (floodplain height over streambed) greater than 18 inches, due to post-construction floodplain deposition or channel incision • Failure of riffle-grade control practices (where present) used to raise water levels
[1] Modified from Group 1 (2019) to account for the unique low-bank conditions of FR projects. The modifications help ensure that the desired elevation(s) for stream/floodplain reconnection are maintained in the face of future upstream storm flows or head-cuts advancing from downstream	

Table 13. Defining Loss of P-3 Pollutant Reduction Function for FR Projects [1]	
Criteria	*Key Visual Indicators for FR Projects*
Channel incision or floodplain sediment deposition increases effective bank height, thereby reducing intended annual stream flow volume diverted to floodplain	• Inability to meet 80% ground or canopy cover targets within the project's designed FTZ • No evidence of overbank deposition and floodplain retention, as signified by a lack of sediment deposition, terraces, wrack-lines or leaf clumps in floodplain • Restored floodplain elevation (floodplain height over streambed) greater than 18 inches above channel or low flow water elevation due to post-construction floodplain deposition or channel incision • Incision or downcutting of channel fill that causes an increase post-restoration bank height • Failure of channel grade control practices used to raise water levels (if using RSB approach)
[1] Modified from Group 1 (2019) to account for the unique low-bank conditions of FR projects. The modifications help ensure that the desired elevation(s) for stream/floodplain reconnection are maintained in the face of future upstream storm flows or head-cuts advancing from downstream	

2.4.4 Protocol-Specific Reach Investigations

Each of the protocols has its own unique work flow to inspect and verify the stream restoration project (Figures 17 to 19).

Protocol 1 Field Work: As shown in Figures 17, the project reach is walked in an "out and back" manner. In the "out" leg (Step 1), the crew rapidly assesses the visual indicators established for Protocol 1, and temporarily flags any location where more detailed measurements need to be taken.

If problems are encountered, more detailed measurements are taken in the "back" leg of Step 2. The crew may measure bank height, exposed soil cover, tree canopy cover or the linear extent of any problem areas (e.g., eroding bed or banks). Photos are taken to document any suspected problem areas and at any pre-defined cross-sections or stations shown on the project drawings.

Protocol 2 Field Work: The rapid survey uses the same general "out and back" method used for protocol 1, but emphasizes the condition of the hyporheic zone within the project limits (Figures 18). The crews:

- Inspect riffles for indicators that show diminished streambed quality
- Measure current bank height at pre-designated stations shown on project as-built or project monitoring plan.
- If no stations are designated, then geo-document the desired bank height measurement.

The general rule is to inspect the zone from edge of stream to top of bank about every 100 to 200 feet of channel riffles. Shorter projects may need to inspect the zone over shorter intervals (e.g., 50 ft).

Field crews should observe indicators in a manner that adequately cover the surface area of the project EHZ to ensure it is still functioning as originally designed. It is very helpful to have post-construction as-built plans that clearly delineate the EHZ areas, as well as providing the average design bank elevations.

Protocol 3 Field Work: The rapid survey combines the same "out and back" reach assessment with an inspection of the reconnected or restored floodplain within the project limits (Figures 19). Spot checks may also be conducted across the floodplain to confirm the reconnection and assess its visual indicators. The crew may also choose to assess Protocol 2 indicators to determine if channel incision is compromising the project.

Field crews should observe indicators in a manner that adequately cover the surface area of the project FTZ to ensure it is still functioning as originally designed. It is very helpful to have post-construction as-built plans that clearly delineate the FTZ and the design elevations of the banks.

Numeric failure thresholds for the reach. After initially determining the proportion of the project reach that may be compromised, the field technicians compare their outcomes to numeric thresholds that may predict unacceptable project failure. If project failure is found to be a possibility, then a second forensic investigation by a more experienced stream restoration professional may be needed to confirm the diagnosis, diagnose the nature and cause(s) of the failure and whether project functions can be recovered by additional work.

2.4.5 Scoring the Performance of Project Reaches

The project is analyzed to determine if the degree of change, relative to the original design, is severe enough to warrant management action. The basic idea is that all stream restoration projects fall into one of three possible management categories, as shown in Table 14.

The categories were deliberately designed to be non-overlapping so there would be room to judge the entire system as a whole. For example, if a project falls between categories (e.g., 15%), professional judgement is needed to answer the question of whether the project is trending toward or away from stability, thereby pushing the project into a lower or higher failure category.

Table 14. Framework for Relating Reach Conditions to Management Decisions

Status	*% Failing*	*Inspections*	*Management Actions*
Functioning or Showing Minor Compromise	0 to 10% of project reach	Re-inspect in 5 years	None Needed Credit Renewed for 5 Years
Showing Major Compromise	20 to 40% of project reach	Conduct immediate forensic investigation to identify cause(s)	Do project repairs and maintenance, as warranted
Project Failure	50% or more of reach	Lose credit and abandon the project or reconstruct a new stable channel	

The method for calculating the percentage of the project reach in poor condition for each protocol is described in Table 15.

Table 15. Examples of how Percent Failure is Defined Along a Project Reach for Each Protocol

Protocol 1	**Protocol 2**	**Protocol 3**
A. Define Restored Banks Over Reach Length[1]	*A.* Define Hyporheic Zone Over Reach Length[2]	*A.* Define Area of Reconnected Floodplain[3]
Example: 1000 ft reach has 2000 LF of restored banks	*Example: 1000 ft reach has 400 LF of reconnected hyporheic zone, both banks would be 800 LF*	*Example: 1000 ft reach has reconnected floodplain on right bank by an additional 10 ft, and additional 20 ft on the left bank = 30,000 ft^2*
B. Estimate Total Impaired Reach Length, for all indicators [4]	*B.* Estimate Length of Impaired Hyporheic Zone, for all indicators [5]	*B.* Estimate Length/Area of Diminished Connection [6]
Example: 100 ft of right bank and 50 ft of left bank are compromised, for a total of 150 ft *(150/2000=7.5%)*	*Example: 100 ft of right bank and 300 ft of left bank are compromised, for a total of 400 ft* *(400/800 = 50%)*	*Example: 300 LF of right bank and floodplain have washed out and are now exposed soil (3000/30,000 =10% of floodplain and 300/2000 = 15% of stream) Total = 25%*
C. Compute Percent Function Loss Over Reach[7] and Compare to Decision Thresholds		
Example: Functioning or showing minor compromise	*Example: Project failure*	*Example: Showing major compromise*

Notes:

[1] Restored bank length can be up to two times greater than the restored reach length

[2] Length of the hyporheic zone along the channel from its initial disconnection extending downstream until connection is resumed, excluding bedrock sections, per design.

[3] Area of floodplain with new or increased reconnection with the channel, per design

[4] Calculated by dividing estimated linear feet of eroding/bare earth by the linear feet restored banks (e.g., 400 feet of eroded bank observed over a 1,000 feet restoration project would be 400/2000=20%).

[5] Done in the same general manner as Protocol 1

[6] Can be measured as % bank height length exceeding design tolerances or % floodplain area not vegetated or otherwise connected

Chapter 3
Bay Managers Guide to the Stream Restoration Practice

The Chesapeake Bay Program Partnership has crafted substantial guidance on how to credit stream restoration projects over the last eight years. Various parts of the original expert panel report have been updated, superseded, appended, modified or replaced since it was originally approved in 2013. Some sense of the magnitude and timing of the approved changes can be found in Table 16. Although these changes have vastly improved the quality of the guidance, they have also created significant version control problems, and created some confusion about what is currently required among both Bay managers and practitioners alike

This document is intended to integrate all the changes together into a single unified document. Each section leads with a box that indicates what's new in the last few years, and a box with links to access more resources that contain important technical details.

Table 16. Timeline of Major Changes to Bay Stream Restoration Crediting

Year	Action
2013	• Stream Restoration EPR Conditionally Approved
2014	• Stream EPR "Test Drive" Completed • CBP BMP Verification Policy Adopted
2015	• CBT Pooled Monitoring Funds Priority Research
2016	• Fact Sheet Released
2017	• Phase 6 Watershed Model Replaces Phase 5.3.2 Version
2018	• FAQ Document Released • USWG Charges 4 Groups to Revisit EPR
2019	• Stream Restoration Verification Memo Approved • New Protocol 5 Approved for OGS Projects
2020	• Protocol 1 Updates Approved • Protocol 2 and 3 Updates Approved • Non-Tidal Wetland Restoration EPR Approved

This chapter is targeted to the Bay manager, simply defined here as anyone who needs to know enough to make good decisions on how to credit, report, stack, track, verify or otherwise handle stream restoration projects submitted for pollutant removal credit in the Chesapeake Bay watershed.

Bay managers may include staff in local, state or federal agencies, project sponsors and funders, and private sector managers that may not be directly involved in individual project design and construction, but need to provide more general advice to those that do.

This version is current and up to date as of the summer of 2021, and will be periodically updated in the future as the CBP Partnership develops additional guidance.

Section 3.1 Qualifying Conditions

At some point, every Bay manager will be asked to decide whether or not a proposed stream project qualifies for pollutant reduction credit. This section outlines the specific conditions to be eligible for Chesapeake Bay TMDL pollutant reduction credit, as established by the original Stream Restoration Expert Panel, and subsequently modified over the years. The qualifying conditions are designed to promote a watershed-based approach for screening and prioritizing stream restoration projects to improve stream function and habitat.

What's New Since 2014
• Expanded environmental conditions to reduce unintended consequences associated with stream restoration projects (described further in Section 3.5.2) • Clearer definitions of what constitutes acceptable and unacceptable forms of bank armoring • Clarification of the crediting status for NRCS stream projects • Specific conditions for floodplain reconnection/legacy sediment removal projects • New qualifying conditions for OGS practices located in the headwater transition zone (i.e., Protocol 5 projects).

3.1.1 Core Qualifying Conditions

The following qualifying conditions apply:

- Stream restoration projects that are primarily designed to protect public infrastructure by bank armoring or rip rap do not qualify for credit. Limited hard bank stabilization may be needed to protect critical public infrastructure within a larger stream project, but these are subtracted from the pollutant reduction credit, depending on the nature and length of the bank armoring technique employed. (Note: detailed restrictions on bank armoring are now included as a specific qualifying condition for Protocol 1 – see Section 3.1.3).

- The stream reach must be greater than 100 feet in length and be still actively enlarging or degrading in response to upstream development or adjustment to previous disturbances in the watershed (e.g., a road crossing and failing dams). (Note: Due to their unique location, Protocol 5 OGS practices are exempted from the 100-foot reach length restriction).

- Most projects will be located on first- to third-order streams, but can be targeted on fourth and fifth order streams if found to contribute significant and uncontrolled amounts of sediment and nutrients to downstream waters. Larger scale projects may be warranted to achieve desired watershed treatment goals.

- The project must utilize a comprehensive approach to stream restoration design, addressing long-term stability of the channel, banks, and floodplain.

- Special consideration is given to projects that are explicitly designed to reconnect the stream with its floodplain or create wetlands and instream habitat features known to promote nutrient uptake or denitrification.

- Stream restoration projects must meet post-construction monitoring requirements, exhibit successful vegetative establishment, and any initial project repairs required under their construction permit.

- A qualifying project must demonstrate that it will maintain or expand existing riparian vegetation in the stream corridor, and compensate for any project-related riparian losses in project work areas as determined by regulatory agencies.

- All qualifying projects must have a designated authority responsible for inspections, routine maintenance, long-term repairs and credit verification.

Additional environmental qualifying conditions were adopted to ensure that restoration projects increase habitat and functional uplift in streams and floodplains, while simultaneously reducing the possibility for any unintended environmental consequences. The following minimum environmental conditions apply to all stream restoration projects in order to qualify for credits:

- Each project must comply with all state and federal permitting requirements, including 404 and 401 permits, which may contain conditions for pre-project assessment and data collection, as well as post-construction monitoring.

- Advance project consultation with state and federal permitting agencies is highly recommended (Note: In 2020, the U.S. Army Corps of Engineers issued a general permit for Chesapeake Bay TMDL projects, which should be consulted for any stream restoration project—a link can be found in the Resources Box).

- Stream restoration is intended to be a carefully designed intervention to improve the hydrologic, hydraulic, geomorphic, water quality, and ecological condition of degraded urban streams, and must not be implemented for the sole purpose of nutrient or sediment reduction.

- A qualifying project must meet certain presumptive criteria to ensure that high functioning portions of the urban stream corridor are not used for in-stream stormwater treatment (i.e., where existing stream quality is still good). These may include one or more of the following:

    - Geomorphic evidence of active stream degradation (i.e., high BEHI score)
    - An IBI of fair or worse
    - Hydrologic evidence of floodplain disconnection

  - Evidence of significant depth of legacy sediment in the project reach

- Stream restoration should be directed to areas of severe stream impairment, and the use and design of a proposed project should also consider the level of degradation, the restoration needs of the stream, and the potential functional uplift. Each project should measure functional uplift within a stream, using methods such as the functional pyramid approach developed by Harman et al (2011).

- Projects should always maintain and improve the passage of aquatic organisms when possible.

- The effect of stream restoration on stream quality can be amplified when effective upstream BMPs are implemented in the catchment to reduce runoff, stormwater pollutants and improve low flow hydrology.

- State and federal permitting agencies reserve the discretion to apply this guidance to support better permit decisions and always retain the authority to make permit decisions and/or establish permit conditions for TMDL-driven stream restoration projects.

- Likewise, decisions about how to weigh the potential for temporary adverse impacts on existing site environmental qualities against the long-term environmental benefits are left to the appropriate regulatory agencies.

3.1.2 Application of Protocols to Rural Streams

The urban stream restoration protocols can also be applied to projects located in rural areas. While urban and rural streams can differ with respect to their hydrologic stressors, nutrient loadings and geomorphic response, they also share the pervasive impact of floodplain disconnection and/or legacy sediments often observed both kinds of watersheds (Figure 20).

The experts agreed the four crediting protocols developed for urban streams should work reasonably well in rural streams, depending on the severity of bank erosion and floodplain disconnection. Rural stream projects are eligible for credit as long as they meet all relevant qualifying conditions, environmental considerations and verification requirements. The CBP Agriculture Workgroup is currently investigating how to properly credit several NRCS stream practices, and are expected to provide guidance soon.

Three types of non-urban stream restoration projects, however, do not qualify for the removal credit. These include:

- Enhancement projects where the stream is in fair to good condition, but habitat features are added to increase fish production (e.g., trout stream habitat, brook trout restoration, removal of fish barriers, etc.)

- Projects that seek to restore streams damaged by acid mine drainage
- Riparian fencing projects to keep livestock out of streams (these projects may qualify for a separate agricultural BMP credit).

3.1.3 Protocol-Specific Qualifying Conditions

Certain project design conditions must be satisfied in order to be eligible for credit under the individual crediting protocols, as follows:

Protocol 1: Armoring Definitions and Restrictions

Bank armoring installed for the sole purpose of infrastructure protection (i.e., sanitary lines that run perpendicular and/or parallel to the stream) will not be credited. The use of softer natural materials (i.e., vegetation and wood) and floodplain reconnection are encouraged as preferable options to stabilize banks and dissipate energy.

Boulder and cobble may be appropriate for restoration design if they are commonly found in the natural substrate of the project's physiographic region (i.e., in-stream cobble provides habitat for benthic macroinvertebrates in the Piedmont, but is not considered appropriate for the coastal plain). Further, site constraints such as steep gradients, erodible soils, or hydraulic factors present barriers to preferred restoration design approaches.

In particular, reaches draining highly impervious subwatersheds may experience velocities that require other engineering solutions to provide stable downstream conditions. Large restoration projects may also contain limited sections where existing buildings or infrastructure require protection even if the larger reach is designed to restore the channel and achieve functional uplift.

To address these realities, three categories of armoring practices were defined and are subject to limitations, as shown in Table 17.

Table 17. Designation of streambank armoring practices

Tier	Examples
Non-Creditable Definition: Hard, permanent structures used to protect critical infrastructure and stabilize banks. Techniques are not consistent with long-term, comprehensive restoration approaches**.**	• Concrete Retaining Wall • Sheet Piling/Planking • Gabion • Engineered Block Walls • A-Jacks • Dumped Rip Rap
Creditable w/ Limits Definition: Large rock or boulder structures that harden a limited portion of a bank or bank toe in a localized area	• Localized stone toe protection • Boulder Revetments • Non-biodegradable soil stabilization mats • Imbricated Rip Rap
Creditable Definition: Structures that mimic naturally occurring streambank materials, features that provide aquatic habitat function, and limited in-stream grade control	• Root wad Revetments • Live stakes/coir logs • Soil lifts[2] • Riffle-weir series (including cobble in appropriate physiographic regions) • Berm-pool cascades • J-hooks and cross-veins

Qualifying Conditions for Floodplain Reconnection Projects (Protocol 2 and 3)

The following qualifying conditions have been developed for all FR projects:

1. *Project must meet applicable floodplain management requirements in the stream corridor.* Any individual stream restoration project should be assessed with hydrologic and hydraulic models to demonstrate whether it increases water surface elevations or has adverse downstream flooding impacts. In general, these analyses are based on design storm events and flood risk conditions established by the appropriate local or state floodplain management agency (e.g., the 100-year storm event).

2. *Project must evaluate the duration of floodplain ponding in the context of the restoration goals.* Micro pools and long-duration ponding of water on the floodplain is essential for amphibian habitat, but large open water features may adversely impact the desired riparian vegetative community. In evaluating a potential restoration site and design, consider the potential adverse effects of extended open water ponding based on the soil characteristics, plant community, amphibian and other aquatic habitat goals.

3. *Project must demonstrate consideration of potential unintended consequences of the restoration* The project should document that a site impairment exists and that the interventions or restoration work proposed are appropriate to address the impairment. The proposed design should demonstrate that a positive ecological functional uplift (or change) for the stream and associated riparian system will result.

FR-RSB Qualifying Conditions

The stream experts developed additional qualifying conditions for floodplain restoration projects that access the floodplain by raising the streambed, including:

1. *Project must demonstrate that it either provides, or is tied into existing upstream and downstream grade controls* to ensure the project reach can maintain the intended stream access to the floodplain.

2. *Project must clearly define the boundary of the effective hyporheic zone*. For FR-RSB projects the EHZ is a maximum of 18 inches deep in the floodplain soil profile, and extends only to those areas that are regularly inundated after the streambed is raised. The actual dimensions must be confirmed by site investigations that define stream flow conditions, root zones, aquifer conditions and the pre-project water table conditions.

3. *Project must demonstrate that baseflow conditions are not reduced as a result of the restoration* (ex. change from perennial to seasonal intermittent flow).

FR-LSR Qualifying Conditions

The stream experts developed additional qualifying conditions for floodplain restoration projects that access the floodplain by removing legacy sediments. This category of projects should meet the following minimum qualifying conditions:

1. *Presence of legacy sediment deposits or other floodplain impairment*. Legacy sediments must be present in the project reach to a depth that has impaired aquatic ecosystem function. Legacy sediment includes any deposits that have occurred since European settlement, including very recent sediment deposits, often created by features such as mill dams, road embankments, floodplain fill and other kinds of stream corridor impairment.

2. *Floodplain connection to valley bottom aquifer*. The design objective is to restore a plant/groundwater connection within the floodplain, so that most of the root mass of the floodplain vegetation is in direct contact with the underlying hyporheic aquifer. In cases where the historic hyporheic aquifer cannot be accessed due to modern controls (i.e., culverts or utility crossings), the objective is to plug the flow of the underlying aquifer so as to create a new hyporheic zone using cobbles, gravel and/or sandy materials.

3. *Defined boundaries for the channel(s), floodplain and valley bottom.* The restored channel and floodplain dimensions are based on field testing that define the key vertical and lateral sediment boundaries of the existing floodplain and the hyporheic aquifer beneath it.

4. *Removal of legacy sediments is the primary means to restore floodplain reconnection.* This condition applies only to projects that primarily remove legacy sediments to reconnect the floodplain, and not projects that provide reconnection by raising the streambed.

Qualifying Conditions for Protocol 5 Projects (Outfall and Gully Stabilization)

These projects are located in the headwater transition zone in ephemeral channels, and are subject to their own unique qualifying conditions to be eligible for credit:

1. The channel or gully slope below the source must exhibit predictive indicators for severe erosion or hill-slope failure and must be observed to be actively enlarging or degrading.

2. OGS projects must meet post-construction stability criteria, successfully establish needed vegetation and maintain or improve existing native riparian vegetation in the headwater stream corridor, to the extent possible. Projects should follow regulatory agency guidance regarding compensation for any losses of forest, wetlands and sensitive habitats within project work areas.

3. Storm drain pipes are permissible in cases where they are needed to ensure channel stability and do not create new aquatic organism passage issues.

4. OGS projects are not subject to the minimum 100-foot project reach length that applies to other stream restoration projects. This relaxation is appropriate given the inherent slope/degradation issues in steep systems and the large sediment discharges that can occur in these short upper reaches. Actual project length for OGS projects is determined by equilibrium slope analysis, but are normally less than 500 feet in length.

Credit for Protocol 1 cannot be combined with credit for Protocol 5 within the same project reach.

Section 3.2 Grandfathering

Numerous grandfathering provisions were adopted by the Partnership to avoid penalizing projects that were in the design and construction "pipeline" while the new protocols were being developed. This "ramp-up" period allowed practitioners to gradually adjust to meet the new guidelines and protocols that were recently approved.

At this point, all grandfathering provisions for stream restoration projects have expired.

- Any project constructed or under contract after July 1, 2021 must now adhere to the definitions, qualifying conditions and protocol adjustments, as laid out in this document.

- Any project constructed or under contract before July 1, 2021 have the option to (a) follow the new recommendations or (b) adhere to definitions, qualifying conditions and protocol methods outlined in the original expert panel report.

The final authority for interpreting prior grandfathering decisions for individual projects is reserved by the appropriate state regulatory agencies.

Some of the practical implications of this change for Bay managers are outlined in the box below:

What Are the Implications of the End of Grandfathering?
All project grandfathering provisions have expired for projects designed and constructed after July 1, 2021
Interim Methods No Longer Accepted: • Use of default stream restoration removal rate (pounds/lf) to report credit • Use of default parameters on Protocol 1 calculations
What is Now Required • The new protocols are now the sole method for calculating pollutant reduction credits • Armoring restrictions are now in effect for Protocol 1 • New boundaries established for Protocols 2 and 3 (e.g., EHZ and FTZ) • Older rates and protocol steps are significantly modified for Protocols 2 and 3
Grandfathering may not apply to certain NRCS stream habitat and improvement practices whose crediting is being investigated by the Agricultural Work Group

Section 3.3 Practice Reporting, Tracking and Stacking

Bay managers frequently get questions about what needs to be reported to their state agency to get credits, as well as how and when protocols can be combined or "stacked" together. Many local managers also want to learn how to track their inventory of stream projects over time so they can better manage their monitoring and verification requirements. This section provides the answers to these important questions.

What's New Since 2014
• BMP reporting requirements have been simplified and streamlined • The default removal rate (lbs/lf/yr) is no longer accepted for credit reporting • Expanded recommendations on project record-keeping to support future verification • Specific guidance on which protocols can be stacked together for credit • Technical resources on methods for tracking the local inventory of restoration projects

3.3.1 Practice Reporting and Record-Keeping

Restoration Reporting to the State.

The information that is required to be reported to the Chesapeake Bay Program to earn credit for stream restoration practices has been streamlined since the expert panel report was fully approved in 2014. The installing agency must submit basic documentation to the appropriate state agency to document the nutrient and sediment reduction claimed for each individual stream restoration project installed. Localities should check with their state agency on the specific data to report for individual projects. The current reporting criteria for stream restoration practices are outlined in Wood et al (2018) and includes:

- *BMP Name:* Stream Restoration
- *Length Restored:* (ft)
  Protocol(s) Name and associated unit amount (lbs)
  - Protocol 1 TN; Protocol 1 TP; Protocol 1 TSS;
  - Protocol 2 TN;
  - Protocol 3 TN; Protocol 3 TP; Protocol 3 TSS
  - Protocol 5 TN: Protocol 5 TP: Protocol 5 TSS
- *Land Use:* The default land use is "Stream Bed and Bank"
- *Geographic Location:* Qualifying NEIEN geographies including: Latitude/Longitude; or County; or County (CBWS Only); or Hydrologic Unit Code (HUC12, HUC10, HUC8, HUC6, HUC4, State (CBWS Only)
- *Date of Implementation*: year the project was completed

If post-restoration monitoring is conducted to recalculate the project restoration efficiency, then it needs to be reported again. The new restoration efficiency for the stream restoration project replaces the original record. The re-calculated efficiency is then back-dated to ensure that higher reductions are credited for all of the years after project installation.

The original expert panel provided default nutrient and sediment removal rates per linear foot of stream restoration. These default rates were intended for project planning and screening purposes, and also for reporting older projects that did not conform to the protocols. Since then, however, the CBP Partnership agreed to discontinue the use of default rates for project reporting. Consequently, default rates should no longer be used to report project credits to the state. Project designers are now required to directly calculate their removal credits based on one or more of the protocols that apply to their individual sites[6].

Additional Reporting Requirements for OGS projects:

- Outfall pipe diameter (in)
- Drainage area (acres) and its impervious cover (%) [MD only]
- Primary outfall restoration technique used

Project Record-keeping.

The installing agency should maintain an extensive project file for each stream restoration project installed (i.e., construction drawings, as-built survey, digital photos, post construction monitoring, inspection records, and maintenance agreement). The file should be maintained for the lifetime for which the load reduction will be claimed.

In addition, the project file should contain information to support future verification efforts, such as:

- Project length, adjusted for armoring restrictions
- Primary design approach
- Protocol(s) used
- Pre- and post-channel and floodplain dimensions and EHZ and FTZ boundaries
- Portion of project reach with armoring practices subject to credit limitations
- Documentation of protocol calculations and supporting data
- Wetland delineation data and reforestation plan

[6] The CBP decision allowed for NRCS stream restoration practices to continue reporting the default rate until the Agriculture Workgroup provides new guidance for this group of practices.

3.3.2 Protocol Stacking

Some protocols can be combined together within the same reach, while others cannot. The following is a quick summary of the conditions under which more than one protocol can be "stacked" together to earn more pollutant removal credit. The rules for stacking are described below:

- Protocols 1, 2 and 3 can all be reported independently, or they can be stacked together in any combination (i.e., as long as they meet the respective protocol conditions for prevented sediment, hyporheic exchange and/or floodplain reconnection within the project reach)

- Protocol 5 (Outfall and Gully Stabilization) cannot overlap Protocol 1 (Prevented Sediment) within the same project reach. The choice of which protocol to apply should be based on the dominant erosion mechanism along the channel profile. Protocol 1 is applied in reaches dominated by lateral erosion, whereas Protocol 5 is applied to reaches experiencing severe vertical degradation such as headwater transition zone in ephemeral channels especially below storm drain outfalls.

- Protocol 5 can be reported independently, or be stacked with protocols 2 and 3 in the same project reach, as long as it meets the conditions for hyporheic exchange and/or floodplain reconnection, which is fairly uncommon.

- Wet-channel RSC practices installed on perennial or intermittent stream channels may be credited using either Protocol 1 or 5 but the two credits c*annot* overlap.

- Protocol 4 can be reported independently as an upland retrofit alone, or in some cases, can be combined with Protocol 5 in the same reach. In this situation, the dry-channel RSC practices installed in ephemeral stream channels is credited as both a stormwater retrofit (Protocol 4) and an OGS practice (Protocol 5). Protocol 4 reductions are subtracted from the pollutant load generated from upland urban catchment, whereas the Protocol 5 reductions are subtracted from the urban stream bank load.

  The pollutant reduction impact of stream restoration projects is *independent* of any reduction achieved by upstream retrofits or other approved urban practices in the contributing drainage area.

  Note: Protocol 4 applies to dry channel regenerative stormwater conveyance projects that treat stormwater runoff in upland areas, and are not technically considered a stream restoration practice.

3.3.3 Tracking Systems for Stream Restoration Projects

Bay managers understand the need for good systems to track project and inspection data over time to make better management decisions about their inventory of restoration projects. Several good examples of effective ways to keep track of stream restoration project data are described below and in the accompany technical resource box.

Resources for Project Tracking
Template for Chesapeake Bay Nutrient Removal Credit Verification *Credit: Kinsey Hoffman (Hazen)* • https://drive.google.com/open?id=1C6aYs9Cj9-qxnkThxITORE9fAKxf4Bzw
Spreadsheet for Storing Rapid Stream Monitoring Protocol Data • https://chesapeakestormwater.net/download/9498/
Example of Monitoring/Maintenance Plan (River Run SRP) • https://chesapeakestormwater.net/download/9501/
Fairfax County Stream Restoration Scorecards • (Part 1): https://chesapeakestormwater.net/download/9505/ • (Part 2): https://chesapeakestormwater.net/download/9509/

The first approach relies on a simple spreadsheet template to track critical points of potential vulnerability along the project reach. The spreadsheets are used to store and analyze inspection data for a typical project designed using any restoration protocols.

A second approach relies on parts of existing stream assessment tools, such as the Rapid Stream Restoration Monitoring Protocol (USFWS, 2014). Geomorphic and channel data collected as part of this rapid method can quantify several visual indicators. As with the previous method, a spreadsheet has been developed to track project assessment data collected using the rapid protocol.

The third approach involves a concise project monitoring and maintenance plan. A good example of a real-world stream restoration project plan is provided in the resource box. The plan outlines the project goals and objectives, as well as the schedule, map and procedures for field monitoring and long-term maintenance.

The fourth approach involves an asset management system developed by Fairfax County, Virginia. Stream restoration projects are tracked by the public works maintenance division that already oversees other stormwater features (such as wet ponds, extended ponds, green infrastructure and outfalls). Easements are in place prior to construction to have continued access and maintenance responsibility in perpetuity, especially for features that are not owned by the County.

As-built designs of projects are conducted similar to other infrastructure and are monitored every 5 years. The maintenance systems developed for other stormwater assets were adapted for use for stream projects. Given the complicated nature of stream projects, the maintenance process was upgraded to a two-stage monitoring. The first level monitoring being conducted by field staff to observe and document. No action decisions are made without a second level of review by subject matter experts including ecologists, landscape architects, engineers and construction experts, which may or may not require additional measurement.

A simple reference card for each feature, which includes many of the details outlined elsewhere, allows for ready access to project construction details. As-builts, planting plans and construction documents are also archived. A geo-referenced scorecard is housed in a GIS database that will allow project tracking through time. The template for a stream maintenance score card and a prototype for an individual project is provided in the technical resources box.

Section 3.4 Verification and Credit Duration

Bay managers need to fully understand how stream restoration practices are verified to maintain their pollutant reduction credits over time. This section covers the basics of verification, and answers some of the general questions about how it applies to stream restoration projects that Bay managers can expect to encounter.

What's New Since 2014
• Field methods and visual indicators for inspecting stream restoration projects leading up to and beyond their 5-year credit duration. • Numeric triggers and subsequent management actions to assess whether a project is maintaining its pollutant reduction performance over time, and determine whether to fix the project or walk away • For projects being credited under Protocol 1, efficiencies greater than 50% may be allowed for projects that have shown through monitoring that the higher rates can be justified, subject to approval by the states.

3.4.1 CBP BMP Verification Policy

The Chesapeake Bay Partnership endorsed a policy that all urban BMPs must be verified in the field to ensure they are still earning their pollutant reduction credit towards the Bay TMDL (CBP, 2014). Verification is needed to ensure that the practices used for pollutant reduction credit in the Bay:

- actually exist
- are working as intended, and
- are maintained properly over their design life.

The original expert panel did not outline procedures for verifying the performance of stream restoration projects built for pollutant removal credit. This was rectified in 2019, when the USWG approved procedures for field verification of stream restoration projects, after their original construction permit monitoring requirements expire (Group 1, 2019).

3.4.2 General Verification Requirements for Individual Projects

This section describes the basics of what is required to verify projects to maintain credits over time, whereas Chapter 2 describes how verification inspections are conducted in the field and how that data is interpreted to make decisions on whether or not to verify individual projects.

Responsibility for Verification: The agency or jurisdiction that installs the restoration practice is responsible for verification inspections. These inspections are designed to eliminate projects that fail or no longer meet their restoration objectives, and reduce or eliminate their sediment and nutrient reduction credit. Verification inspection also generate useful data on real world projects that can refine future restoration methods and practices.

Most restoration projects undergo monitoring for several years after construction, based on required state and federal permit conditions. Once the original permit expires, however, the responsibility for inspections shifts to the installing agency to ensure that projects are still functioning as designed. The installing agency needs to conduct visual inspections once every 5 years after the date of installation (after the original permit conditions expire) to ensure that individual projects are still capable of removing nutrients and sediments

Initial Verification of Performance. The installing agency will need to provide a post-construction certification that the stream restoration project was installed properly, meets or exceeds its functional restoration objectives and is hydraulically and vegetatively stable, prior to submitting the load reduction to the state tracking database. This initial verification is provided either by the designer, local inspector, or state permit authority as a condition of project acceptance or final permit approval.

Duration of Stream Restoration Removal Credit. The maximum duration for the removal credits is 5 years, although the credit can be renewed indefinitely based on a field performance inspection that verifies the project still exists, is adequately maintained and is operating as designed. The duration of the credit is shorter than other urban BMPs, and is justified since these on-line projects are:

- Subject to catastrophic damage from extreme flood events which are becoming more common as a result of climate change (Wood, 2021).
- Already required to perform 3 to 5 years of post-construction monitoring to satisfy permit conditions

- Sensitive to changes in critical upstream design assumptions that, in turn, alter the runoff flows and sediment loads treated by the project

Visual Indicators of Practice Performance. All five groups of stream experts worked together to develop specific visual indicators that are observed within a project reach to determine whether it is still meeting its water quality function. Their goal was to develop rapid, consistent, and repeatable methods to inspect visual indicators that, in turn, are used to verify whether a project is still performing, at least with respect to its protocol-specific design assumptions pollutant reduction rates.

Field inspection methods: The objective for the field methods was to enable a two-person crew to inspect a thousand-foot project reach in less than four hours (including time spent on documentation and reporting). The new approach utilizes a two-stage inspection process of the entire project reach. The first stage involves a rapid inspection to assess overall project condition, relying on simple visual indicators. The second stage involves a forensic inspection to diagnose the nature and cause(s) of the failure and whether project functions can be recovered by additional work.

The first stage inspects project condition relying on simple visual indicators. The guiding rule is that inspectors are looking for <u>severe</u> departures from the intended design that are <u>clearly</u> compromising its pollutant reduction functions. The basic approach is to walk the entire project reach and look for indicators of the loss of pollutant reduction function in some or all of the project reach. In some cases, observations or measurements may be made at predefined photo stations or cross-sections shown on the post-construction project drawings.

In the second stage, each project is graded on a pass/fail basis, based on the proportion of the reach deemed to be seriously compromised or failing. This is operationally defined as the percentage of each reach that is:

- Functioning or showing minor compromise
- Showing major compromise
- Project failure

Table 18. Numeric Triggers for Management Actions

Status	% of Project Reach Failing	Management Action
Functioning or Showing Minor Compromise	0 to 10%	Re-inspect in 5 years
Showing Major Compromise	20 to 40%	Conduct immediate forensic investigation to identify cause(s)
Project Failure	50% or more	Fix project to recover credit or lose pollutant reduction credit

Qualified stream professionals normally provide quality control on first stage inspections done by field crews, and always when a project fails or falls between failure thresholds. Stream professionals perform subsequent forensic investigations for project owners/sponsors.

Numeric Triggers and Project Down-grading. The new method has numeric triggers to define whether a given project reach passes, is compromised or fails its stage one inspection. If a project fails, a series of management actions are prompted to restore project function or reduce or eliminate the original pollutant reduction credit (see Table 18).

If a field inspection indicates that a project is failing, a locality has up to one year to take corrective maintenance or rehabilitation actions to bring it back into compliance. If the facility is not fixed after one year, pollutant reduction credits for the project are eliminated, and the locality would report this to the state in its annual MS4 report.

Non-permitted municipalities would be expected to submit annual progress reports. The load reduction can be renewed, however, if evidence is provided that corrective maintenance actions have restored its performance.

Section 3.5 Environmental Permitting Considerations

Perhaps the most notable development over the last decade is the enormous controversy generated by the increased mileage of stream restoration projects constructed in many parts of the watershed.

On one hand, many restoration projects can improve stream and floodplain habitat and provide some degree of functional uplift, especially when the reach has already been degraded by upstream land development. On the other hand, poorly assessed, located, designed or constructed projects can exert unintended consequences that degrade stream and floodplain ecosystems. This section outlines the key recommendations for shifting the balance to maximize habitat creation and functional uplift and minimize any potential negative environmental impacts.

What's New Since 2014
• Detailed scientific review of unintended environment consequences associated with stream restoration practices • Best practices developed for project assessment, design, construction and operation • Functional uplift recommendations for floodplain restoration projects • Special environmental conditions for Protocol 5 outfall and gully stabilization projects • New U.S. Army Corps of Engineers permit conditions for Chesapeake Bay TMDL restoration projects

3.5.1 Functional Uplift

The original expert panel strongly endorsed the need to show functional uplift for stream projects primarily built for pollutant reduction credit (USR EP, 2103). They generally recommended the techniques developed by Harman et al (2011) as the preferred way to measure functional uplift for individual stream restoration projects (or a functional equivalent).

Project designers need to understand the underlying functions that support biological, chemical, and physical stream health to ensure successful stream restoration efforts. In particular, it is important to know how these different functions work together and which restoration techniques influence a given function. Stream functions are interrelated and build on each other in a specific order, a functional hierarchy that Harman et al (2011) have termed the “stream functions pyramid”. Once the function pyramid is understood, it is easier to establish clear restoration objectives for individual projects and measure project success (see Figure 21).

The basic steps of functional assessment should include:

- Set programmatic goals and objectives
- Site selection and watershed assessment
- Conduct site-level function-based assessment
- Determine restoration potential
- Establish specific restoration design objectives
- Select restoration design approach and alternative analysis
- Project design review
- Implement post-construction monitoring

In general, the level of detail needed to perform a function-based assessment will be based on the size, complexity and landscape position of the proposed project.

The panel, however, did not make any recommendations on the specific parameters or number of pyramid levels that should be sampled before and after projects are constructed. This omission has created some confusion among sponsors, designers and regulators as to what exactly is expected when it comes to post-permit project monitoring.

While the importance of measuring functional uplift at stream and floodplain restoration projects is widely accepted, the specific details on what "before and after monitoring" design is needed to actually measure it are missing. In addition, guidance is still lacking on which subset of projects require post-permit functional uplift monitoring, and for how long. The hope is that clear and cost-effective guidance will be developed in the next few years by state and federal regulatory agencies, the CBP Stream Health Work Group, the Chesapeake Bay Trust pooled monitoring consortium, and other stream restoration stakeholders.

Functional uplift for floodplain restoration projects: It is important to note that many current assessment methods have not yet been fully calibrated for floodplain restoration projects. Ideally, functional uplift assessments should be done across the entire reconnected stream <u>and</u> floodplain together. In addition, the reference condition to measure functional improvement should be the entire valley bottom ecosystem.

Several recent functional assessment tools developed by Starr and Harman (2015a,b) and Starr et al (2016) may be useful for floodplain restoration projects, but may need to be combined with traditional wetland functional assessment methods such as FHWA, HGM, WET and others.

3.5.2 Unintended Environmental Impacts

All stream restoration design approaches (i.e., NCD, RSC, LSR and their variants) have the potential to cause unintended impacts that degrade the quality of streams and/or floodplains. These impacts have been observed in restored stream channels, floodplains and downstream ecosystems, and are documented in recent research studies in the mid-Atlantic region and elsewhere (Table 19).

Subsequent groups established new environmental conditions for stream restoration projects to minimize unintended environmental consequences and maintain their intended functions over time.

Table 19. Review of Potential Unintended Impacts Associated w/ Stream and Floodplain Restoration Projects

Impact [1]	*Project Stream Channel*
Depleted DO	Associated with stagnant surface waters and high dissolved organic carbon. Often observed as seasonal.
Iron Flocculation	Observed in both restored and unrestored streams. Associated with high dissolved organic carbon, anoxic conditions and the use/presence of ironstone.
Warmer Stream Temps	Associated with loss of tree canopy in the riparian corridor. Stream and floodplain connection to groundwater in the hyporheic aquifer can mitigate increased temperatures.
More Acidic Water	Associated with disturbance of channel and floodplain soils during construction.
More Stream Primary Production	Associated with loss of canopy cover in the riparian corridor.
Benthic IBI Decline	Associated with construction disturbance, with recovery to pre-project levels in some cases.
Construction Turbidity	Sediment erosion during construction, especially when storm flows overwhelm instream ESC practices
	Floodplain/Valley Bottom/Downstream Ecosystems
Project Tree Removal	Riparian/floodplain forest losses are common due to clearing for design and construction access.
Post-Project Tree Loss	Field and lab studies show that long-term soil inundation results in mortality and morphological changes in tree species.
Invasive Plant Species	Construction disturbance and frequent inundation of the floodplain can serve as vectors for invasive species along restored and unrestored streams.
Change in Wetland Type or Function	Changes in vascular plant communities as a result of floodplain inundation are expected and may be desirable or undesirable depending on the habitat outcome.
Downstream Benthic Decline	Associated with changes in habitat conditions, and construction disturbance. Changes may be temporary.
Blockage of Fish Passage	Incision, large drops or structure failures can impede passage. More study needed

[1] Impacts are defined in relation to the stressors measured in a comparable unrestored urban stream/floodplain system.

Based on an extensive research review on environmental impacts, the groups recommended more than 20 "best practices" to follow during assessment, design, construction, and operation of floodplain restoration projects. These practices can be found in Chapter 2 of this document.

All projects require careful field assessment during design and construction to minimize detrimental environmental impacts. In all cases, the appropriate local, state and federal regulatory authorities retain the final decision regarding whether any proposed stream restoration project aligns with their priority restoration and natural resource objectives.

The guidance provided on the environmental impacts of stream restoration projects is advisory in nature and is intended to promote best practices to minimize potential impacts for individual projects to the extent to which they apply.

3.5.3 Special Environmental Conditions for Protocol 5 Projects

The unique nature and location of outfall and gully stabilization (OGS) projects warrants several environmental conditions when credits for Protocol 5 are considered. They include:

- Restoration and stabilization practices should always be tailored to individual site conditions. Where possible, opportunities located out of the stream network should be evaluated first or in conjunction with OGS projects.
- Great care should be taken when proposing or approving the use of pipe extensions, drop structures, and scour protection as part of eligible OGS projects. The flexibility incorporated into the protocol does not include specific limitations on the length of these practices, which provide stability, but do not provide restoration to a pre-impact or natural reference standard condition. These techniques are only allowed if they are needed to sustain channel stability and do not pose barriers to aquatic organism passage or reduce any existing habitat function within the reach.
- Piping and armoring may also increase stream velocity, creating the potential for exacerbated erosion, flooding, or habitat impacts downstream. Piping of streams is typically considered an impact and may require mitigation if there is a loss of function; restriction of these practices to gullies or erosional channels that have minimal function beyond hydrologic conveyance of flow would reduce concerns for potential adverse impacts
- Each OGS project should be assessed based on the guidance provided by the applicable permitting authorities, the best professional judgment of experts in the field, and should be consistent with the principles of ecological restoration.
- Projects or portions of projects that utilize other hard armoring practices such as dumped riprap, trapezoidal concrete channels and gabion features are subject to the armoring credit limitations described in Section 3.1.3.

- Drop structures, extension of an existing storm drain pipes, stormwater collection features, and scour protection or other hard armoring techniques used in OGSPs are not eligible for credit in perennial channels.

- OGSPs should provide functional lift within the project reach, typically as indicated by improvements of Levels 2 (Hydraulics) and when possible 3 (Geomorphology) of the stream function pyramid (Harman et al, 2011). OGSPs usually will not require special project monitoring to assess stream functions Level 4 and 5 (physio-chemical and biological) because these functions are usually minimal or absent in the headwater transition zone prior to any restoration. Promoting lift for Level 4 and 5 is encouraged when applicable.

Technical Resources for Environmental Considerations
2020 COE Chesapeake Bay TMDL General Permit Conditions A function-based framework for developing stream assessments, restoration, performance standards and standard operating procedures. Function-based rapid stream assessment method US EPA Rapid Bioassessment Protocol (RBP) Society for Ecological Restoration Recovery Wheel CBP Presentations on Unintended Environmental Consequences and Co-benefits of Stream Restoration Projects: 2018/2019 Summary of best practices for floodplain restoration projects

Section 3.6 The Bay Watershed Model and CAST

Bay managers need to acquire a basic understanding of the how the Chesapeake Bay Watershed Model (CBWM), and its companion tool, the Chesapeake Assessment and Scenario Tool (CAST) are used to track watershed nutrient and sediment reductions to meet the Bay TMDL as they are delivered from headwater streams, move through rivers and ultimately reach the Chesapeake Bay estuary.

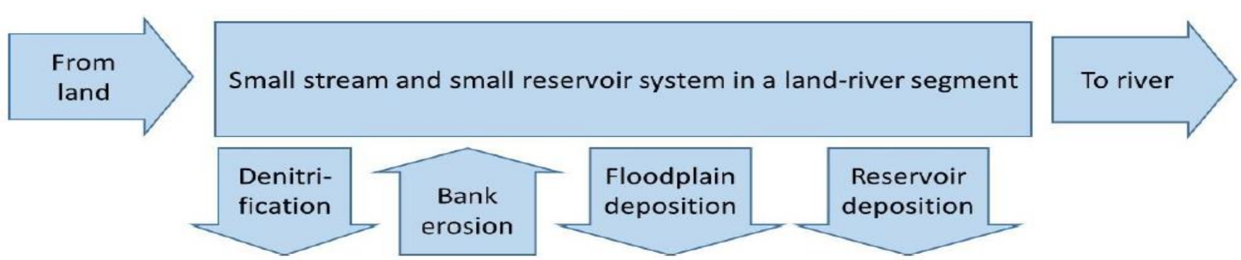
3.6.1 Stream Restoration in the Phase 6 Watershed Model

In 2017, the Chesapeake Bay Program Partnership approved the new Phase 6 Watershed Model, which uses new research and modeling approaches that change how small streams and sediment delivery are simulated and ultimately credited within the Chesapeake Bay TMDL framework. A complete description of how the Phase 6 Watershed Model simulates stream-to-river delivery can be found in the Section 9 of the Final Watershed Model Documentation (Chesapeake Bay Program, 2017).

After some significant improvements in sediment modeling were adopted, the Phase 6 Chesapeake Watershed Model (CBP, 2018) now explicitly calculates sediment and nutrient delivery for individual stream reaches. The Phase 6 Model simulates nutrient and sediment delivery in first through third order streams using data from the Chesapeake Floodplain Network (Noe et al, 2015a). Results indicate that on average, long-term fluxes of sediment and nutrients in streambank erosion and floodplain deposition are in equilibrium, so there is no long-term net change in load in small-order streams from these processes. However, watersheds under development or other form of disturbance (e.g., breach of mill dam, change in agricultural practice, increase in impervious cover) are not in equilibrium, resulting in higher peak flows in streams, with resulting additional streambank erosion.

There are also the impacts from reservoirs and impoundments, which trap sediment and lower their delivery to larger rivers and the Bay. The conceptual approach to sediment delivery is describe in Figure 22.

Figure 22. Processes Represented in Phase 6 Model Stream to River Deliver (CBP, 2018)



There are several key takeaways for Bay managers looking to implement stream restoration projects to meet their Chesapeake Bay TMDL goals:

- In the Phase 6 Model, streambank loads are accounted for separately from upland land use loads. All reductions from stream restoration BMPs are taken from the stream bed and bank load.
- Each catchment has its own unique nutrient and sediment delivery factors, depending on stream and river travel time and presence of reservoirs in its transport path downstream. Therefore, the overall effectiveness of a project in reducing loads to the Bay varies depending on its location in the watershed.
- Fixed sediment delivery factors are no longer part of BMP credit calculations. Sediment and nutrient delivery factors will vary by project location and should NOT be applied to the calculated sediment reductions prior to reporting.
- Therefore, if you know the geographic address of your project, its specific sediment and nutrient delivery ratios can be quickly determined using CAST (EPA, CBP, 2018). Some guidance on a step-by-step method to estimate the unique sediment and nutrient delivery factors for the land-river segment in which a project resides can be found in the Technical Resources Box below.

Technical Resources For CAST
Phase 6 CBWM Documentation CAST Using CAST to Determine Project Specific Sediment and Nutrient Delivery Rates Watershed Maps and Spatial Data

Section 3.7 Priority Research and Engineering Recommendations

Our current understanding of best practice is always evolving as new science sheds light on how aquatic ecosystems respond to restoration interventions along the stream and its floodplain. The original expert panel report triggered a wave of basic and applied stream restoration research across the Bay watershed. Managers need to keep abreast of the latest research developments in order to improve the state of practice.

For the past ten years, stream experts have agreed on research priorities to fill gaps in our understanding of how stream restoration projects work, and how they can be improved to enhance their ecosystem functions. These research recommendations have fallen into four categories:

1. Basic Stream and Floodplain Science
2. Field Methods to Improve Protocol Methods (e.g., BANCS)
3. Methods to Improve Stream Restoration Practice
4. Functional Uplift Metrics and Minimizing Environmental Impacts

Basic Stream and Floodplain Science

- Long-term, interdisciplinary research studies on how streams and floodplains respond to innovative design approaches that emphasize how sediment and nutrient dynamics and ecosystem functions change in projects over time. A good example of the scope for effective multi-year investigations is the Big Spring Run research project (Hartranft et al, 2019).

- Further economic, sociologic, and ecological research to define the value and benefits of local stream restoration projects, beyond nutrient or sediment reduction.

Field Methods to Improve Protocol Methods (e.g., BANCS)

The stream experts recommended several initiatives to improve and standardize BANCS assessments:

- Develop a BANCS Manual with a standard assessment protocol, a photo glossary to increase precision in scoring BEHI and NBS, and establish QA/QC procedures for the field and office.

- *Improve Bank Erosion Rate Curves*: Provide support to develop regional stream bank erosion curves for the BANCS method using local stream erosion estimates throughout the watershed and a statistical analysis of their predicted results. Ideally, measured bank erosion rates within each subwatershed or county would be used to validate the BANCS Method specific to that location.

- Additional research to test the protocols' ability to adequately estimate load reductions in coastal plain, ridge and valley, and Appalachian plateau locations, and to investigate sediment and nutrient dynamics associated with rural stream restoration projects in all physiographic regions of the Bay watershed.

- Given that these data may not be readily available, additional methods for adjusting the BEHI and NBS scores to accommodate local subwatershed characteristics may be useful. For example, adjustments to the BEHI to account for areas with predominantly sandy soils, agricultural channels, or legacy sediment. Develop NBS methods that quantify boundary shear stress

- Develop and test other methods to measure bank retreat rate such as aerial photographs that can be used to estimate historical erosion rates, dendro-geomorphic studies of exposed roots and new shoots, time series channel surveys, and/or bank pins.

Methods to Improve Stream Restoration Practice

- Develop a series of standard regional flow duration curves based on USGS gage data to more accurately estimate floodplain flow diversion.

- Establish an ongoing stream restoration monitoring consortium and data clearinghouse to share project data, train the practitioner and permitting community, and provide ongoing technical support.

- Proper use and application of engineering hydrology, hydraulic, and sediment transport models to assess channel morphology.

- Detailed forensic investigations to identify the causes of failure for projects that do not pass their post-construction verification inspections.

Functional Uplift Metrics and Minimizing Environmental Impacts

- Further work to increase the use of stream functional assessment methods at proposed stream restoration project sites to determine the degree of functional uplift that is attained.

- Short and long-term research efforts focused on the effectiveness of specific best practices in mitigating unintended environmental impacts caused by stream restoration projects. One of the most urgent research priorities is measuring how stream nutrient dynamics respond to different levels of riparian tree loss during and after construction.

- Basic research to define and test new metrics that can effectively predict and measure the degree of functional uplift and/or functional losses achieved by floodplain restoration projects over short- and longer time frames.

Technical Resources on Emerging Research
Chesapeake Bay Trust Pooled Monitoring Initiative for Restoration Research April 2021 Runoff Rendezvous Webcast: *Finished and Un-finished Business in Stream Restoration* CSN Watershed Research Webcasts (ongoing) Maryland Stream Restoration Association CBP Stream Health Work Group Maryland Water Monitoring Council Stream Restoration Subcommittee

Section 3.8 State Regulatory Notes and Guidance

State and federal permitting agencies reserve the discretion to apply this guidance to support better permit decisions and always retain the authority to make permit decisions and/or establish permit conditions for TMDL-driven stream restoration projects. Likewise, decisions about how to weigh the potential for temporary adverse impacts on existing site environmental qualities against the long-term environmental benefits are left to the appropriate regulatory agencies.

Several agencies produced specific regulatory notes during the development of this guidance, which are summarized and linked in the Table below.

Key Regulatory Notes References in Approved Reports
• Bay-wide caveat for BMP Verification guidance • Pennsylvania DEP Position on the Use of the BANCS Method for Protocol 1 • Official EPA position on Protocol 1 • Implementation of Protocol 3 in Maryland • EPA Position on Protocol 5 (OGS)