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SIWM17-17/4844

Crediting Water Quality Benefits from Stream Restoration

Implementation Case Studies and Potential for Crediting Guidance Application

Crediting Water Quality Benefits from Stream Restoration

IMPLEMENTATION CASE STUDIES AND POTENTIAL FOR CREDITING GUIDANCE APPLICATION

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Center for Watershed Protection, Inc.

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Abstract and Benefits

Abstract:

This research project highlights municipality experiences with implementation of the Chesapeake Bay Program (CBP) stream restoration crediting protocols across the Chesapeake Bay Watershed at the state and local municipality level. It also examines feedback from states outside of the Chesapeake Bay watershed who have adopted or are considering adopting the Water Research Foundation (WRF) stream restoration crediting guidance. This was accomplished through a review of stream restoration monitoring case studies, a review of stream restoration crediting and trading programs, and surveys of states and municipalities both inside and outside of the Chesapeake Bay watershed. The results of this project yielded valuable information about the current and potential future use of the crediting protocols, including the need for protocol adaptability, establishment of crediting and trading programs, and the needs of potential users.

Benefits:

- Applies the study results from the WRF stream restoration crediting guidance (WERF1T13) under a real-world setting.
- Provides documentation of monitoring studies that WRF can use to validate and/or update the crediting guidance.
- Summarizes the interest and impediments for adoption of the crediting guidance by state agencies and municipalities nationwide.
- Provides examples to help utilities and municipalities learn how to apply the crediting guidance to implement stream restoration/trading programs.
- Identifies training needs that WRF can provide to help bolster adoption of the crediting guidance.

Keywords: Stream restoration, crediting, monitoring, surveys, case studies.

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Acronyms and Abbreviations

BANCS	Bank and nonpoint source consequences of sediment
BMP	Best management practice
CBP	Chesapeake Bay Program
CWP	Center for Watershed Protection
DEM	Digital elevation model
Expert Panel	Chesapeake Bay Program stream restoration expert panel
IC	Impervious cover
LID	Low impact development
MDA	Maryland Department of Agriculture
MDE	Maryland Department of the Environment
MD SHA	Maryland State Highway Administration
MS4	Municipal Separate Storm Sewer System
NCD	Natural channel design
NPDES	National Pollutant Discharge Elimination System
O&M	Operation and maintenance
PA DEP	Pennsylvania Department of Environmental Protection
PRP	Pollution reduction plan
QAPP	Quality assurance protection plan
RSC	Regenerative stormwater conveyance
SCM	Stormwater control measure
TMDL	Total maximum daily load
USGS	United States Geological Survey
VA DEQ	Virginia Department of Environmental Quality
WLA	Wasteload allocation
WRF	Water Research Foundation

Executive Summary

The WRF stream restoration crediting guidance (WERF1T13) includes the CBP stream restoration crediting protocols (Schueler and Stack 2014) and was developed to provide a general technical framework for quantifying the water quality benefits of a specific suite of stream restoration practices, focusing on sediment and nutrients (Bledsoe et al. 2016). The stream restoration crediting guidance focuses on the technical underpinnings of crediting approaches for stream restoration projects, as opposed to programmatic or regulatory considerations related to crediting programs. There are multiple components, processes, and administrative requirements for a successful crediting program. This research project highlights municipality experiences with implementation of the Chesapeake Bay Program (CBP) stream restoration crediting protocols across the Chesapeake Bay Watershed at the state and local municipality level. It also examines feedback from states outside of the Chesapeake Bay watershed who have adopted or are considering adopting the Water Research Foundation (WRF) stream restoration crediting guidance. The results of this project yielded valuable information about the current and potential future use of the crediting protocols, including the need for protocol adaptability, establishment of crediting and trading programs, and the needs of potential users.

This project included an examination of monitoring case studies within the Chesapeake Bay Watershed that can potentially be used to validate the stream restoration protocols. Monitoring studies for projects that have used the protocols were identified as part of the Stream Restoration Crediting Users Survey (Chapter 4), review of the literature and personal knowledge. After review of the monitoring case studies within the Chesapeake Bay watershed, it was difficult to find statistically robust monitoring studies that included upstream-downstream and before and after paired watershed monitoring designs because they are expensive, take time and training. Funding options are limited as the Chesapeake Bay Trust is the only source of grant funding within the Chesapeake Bay watershed that will pay for statistically robust monitoring designs through their Restoration Grant Program (https://cbtrust.org/grants/restoration-research/). Further, since the protocols were developed in 2014, there has been insufficient time for organizations to mobilize and collect monitoring data that would provide statistically meaningful results. Most of the studies identified addressed only certain questions (e.g., Frederick County, MD and District of Columbia) that would improve the amount of sediment and nutrient load reduction credit they would receive and were not specifically designed to test the accuracy of the protocols except for the 50% restoration efficiency default value for one of the protocols. However, there are several studies identified that while not specifically designed to validate the protocols should have results that can be used for this purpose. Most of the studies included in Table 2-1 are still underway and results are pending. WRF should follow up with the study contacts upon completion to obtain the results and consider their use as part of a strategy to continually adapt the crediting protocols based on the best available data.

Stream restoration projects may provide pollutant trading and mitigation opportunities where water quality regulatory programs require pollutant reduction within a watershed. Stream restoration crediting and trading programs in Maryland, Pennsylvania, and Virginia were reviewed as part of this project. Virginia is the only state within the Chesapeake Bay watershed that utilizes the CBP crediting protocols as part of its Chesapeake Bay Watershed Nutrient Credit Exchange Program at this time. As of March 2017, there have been six applications for stream restoration to Virginia's nonpoint source nutrient bank and there is currently only one stream restoration project to date listed in Virginia's Nutrient Credit Registry. Maryland's trading program is currently under development and a crediting method as part of its draft guidance for relating stream restoration to impervious cover equivalency for purposes of calculating progress towards meeting Municipal Separate Storm Sewer (MS4) permits. Maryland Department of the Environment (MDE) has indicated that the crediting method will likely be changed to align with the protocols developed for the Chesapeake Bay and expects to finalize the Trading Program by the Fall of 2018. Pennsylvania's trading program is currently not designed to include MS4s or the urban sector and no stream restoration projects have been used to generate credits. Although Pennsylvania does not currently have a trading program for MS4s, the PA Department of Environmental Protection (DEP) has provided guidance to Phase II MS4s that would allow for offsets. For those municipalities within the Chesapeake Bay Watershed, stream restoration projects must follow the CBP crediting protocols.

This project also included a literature review focused on watershed processes and channel reconfiguration as practices for restoring streams. WRF defined watershed processes as being actions taken throughout a watershed but outside of the stream corridor itself to mitigate the damaging effects of land use change or other disturbances such as stormwater retention or detention ponds. While controlling watershed processes from the watershed is generally recognized as one of the most cost-effective approaches to restoring streams, it was not specifically included in the WRF stream restoration crediting guidance because of the limited quantifiable evidence on its effect on stream processes. Likewise, restoring streams through channel reconfiguration was not incorporated into the WRF crediting guidance. Channel reconfiguration is typically associated with other stream restoration techniques, making it difficult to isolate the pollutant removal benefits of channel changes alone. The literature review provides a summary of journal articles and white papers to help gain a better understanding of the benefits and limitations of these two practices. It builds upon a previous literature review by Lammers (2015) that was conducted to support development of the WRF stream restoration crediting guidance. The literature review found that the control of watershed processes and channel reconfiguration remain a needed area of research and WRF should continue to exclude these as standalone strategies from the crediting guidance until future research suggests otherwise.

The final component of this project included surveys distributed to states and municipalities within and outside of the Chesapeake Bay watershed regarding their use or possible interest in crediting guidance for stream restoration projects developed by WRF in 2016. The surveys were conducted between March 6 and April 6, 2018. Within the Chesapeake Bay watershed, the majority of survey respondents are using the CBP stream restoration crediting protocols or other MS4 guidance documents which refer to the protocols to calculate water quality benefits from stream restoration projects. Regulatory requirements drive the need for crediting stream restoration projects, with the majority of MS4s indicating permit requirements and the Chesapeake Bay TMDL as the primary reason for implementation of stream restoration projects. In comparison, most survey respondents outside of the Chesapeake Bay watershed that are implementing stream restoration projects reported that they do not calculate water quality benefits. Of those that do, none (except two respondents from Wright Water Engineers) use the WRF stream restoration crediting guidance. The majority of respondents indicated they were not aware of either the CBP stream restoration crediting protocols or the WRF stream restoration crediting guidance. The ones that are aware are not using the guidance due to being unsure of the methodology, a focus other than water quality benefits, and a lack of regulatory drivers.

Within the Chesapeake Bay watershed, a third of the MS4 respondents reported that they don't use the stream restoration protocols for numerous reasons, including having Total Maximum Daily Loads (TMDLs) that focus on pollutants other than nutrients and sediments, confusion over how the protocols apply to the types of projects they do, and that the protocols are too complicated. Outside of the Chesapeake Bay watershed, survey respondents were divided about whether they'd be interested in using the WRF stream restoration crediting guidance in the future. There is a concern for state acknowledgement of the guidance first and an interest in learning more about the guidance first.

The majority of survey respondents from both inside and outside the Chesapeake Bay watershed indicated that training workshops would be the most beneficial for using the stream restoration crediting protocols. In addition, 20% of MS4s within the Chesapeake Bay watershed indicated that a list of consultants with demonstrated knowledge of the protocols would be useful. WRF should consider a targeted outreach and education campaign for the WRF stream restoration crediting guidance that first focuses on state agencies. Further outreach and education of municipal agencies would be beneficial after the states are aware of the guidance and support its use as an acceptable crediting application.

CHAPTER 1

Introduction

Stream restoration is a billion-dollar industry across the nation and is expected to grow exponentially to address water quality needs. In the Chesapeake Bay watershed alone (Figure 1-1), approximately 700 miles of stream restoration projects are expected to be implemented through 2025 to achieve the nutrient and sediment load reductions defined by the Chesapeake Bay TMDL (Schueler and Stack 2014). Most of the Chesapeake Bay and its tidal waters are listed as impaired for aquatic life uses under the Clean Water Act Section 303(d) because of excess nitrogen, phosphorus and sediment. The TMDL identifies the necessary pollution reductions of nitrogen, phosphorus and sediment across Delaware, Maryland, New York, Pennsylvania, Virginia, West Virginia and the District of Columbia and sets pollution limits necessary to meet applicable water quality standards in the Bay and its tidal rivers and embayments by 2025 (EPA 2010). These states have agreed to follow the BMP's protocols approved by the Chesapeake Bay Program (including stream restoration) through the voluntary Chesapeake Bay Agreement (https://www.epa.gov/sites/production/files/2016-01/documents/attachment1chesapeakebaywatershedagreement.pdf).

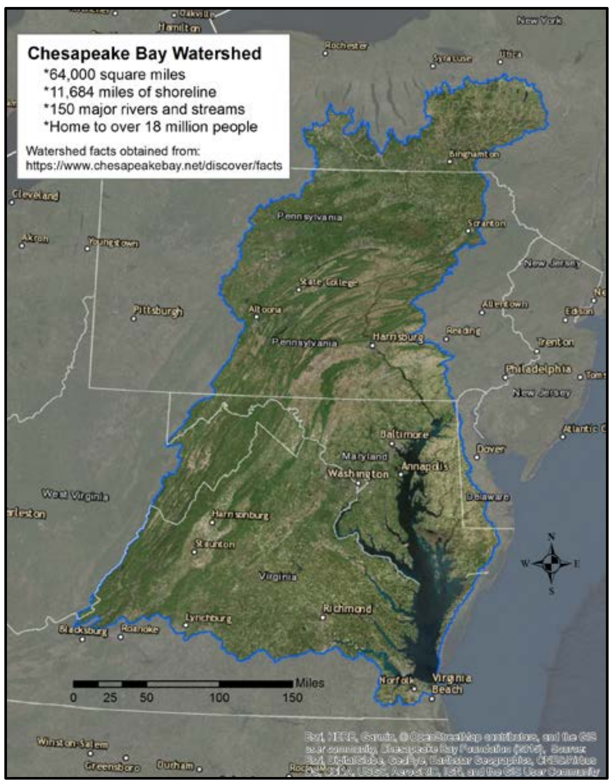


Figure 1-1. Chesapeake Bay Watershed Overview.

The CBP stream restoration crediting protocols (Schueler and Stack 2014) were approved in 2014 and since that time, states and municipalities within the Chesapeake Bay watershed have been implementing them to help meet their respective TMDL load reductions. The three CBP crediting protocols include: Protocol 1) credit for prevented sediment during storm flow; Protocol 2) credit for in-stream and riparian nutrient processing during base flow; and Protocol 3) credit for floodplain reconnection volume. The WRF stream restoration crediting guidance (WERF-1T13) was completed in 2016 and includes the CBP stream restoration crediting protocols (Schueler and Stack 2014). The guidance was developed to provide a general technical framework for quantifying the water quality benefits of a specific suite of stream restoration practices, focusing on sediment and nutrients, which is currently not available from the U.S. EPA and state regulatory agencies (Bledsoe et al. 2016). The findings can be incorporated into local/regional settings to evaluate the feasibility for obtaining credits from stream restoration efforts. As a parallel effort, WRF developed the Stream Restoration database (WERF-U5R14) to be used as a tool to help support stream restoration water quality crediting programs, stream restoration practice selection and design efforts, and stream restoration performance evaluations. The CBP stream restoration crediting protocols, WRF crediting guidance, and WRF stream restoration database are available at:

- CBP Stream Restoration Crediting Protocols

https://www.chesapeakebay.net/documents/Stream_PanelReport_Final_08282014_Appendices_A_G.pdf.

- WRF Stream Restoration Crediting Guidance (WERF-1T13)

https://www.werf.org/a/ka/Search/ResearchProfile.aspx?ReportId=WERF1T13

- WRF Stream Restoration Database (WERF-U5R14)

http://www.bmpdatabase.org/stream.html.

Stream restoration projects may provide pollutant trading and mitigation opportunities where water quality regulatory programs require pollutant reduction within a watershed. Environmental crediting concepts have been developed and are continually evolving via state and federal water quality trading policies and programs and as part of stream and wetland related mitigation under Section 404 of the Clean Water Act. Water quality trading has focused on both point sources (e.g., wastewater treatment) and non-point sources (e.g., agriculture), but increased nutrient loading and decreased nutrient processing in degraded stream systems have not been recognized and included (Bledsoe et al. 2016). However, stream restoration is an increasingly common practice that can influence water quality in degraded systems.

The stream restoration crediting guidance focuses on the technical underpinnings of crediting approaches for stream restoration projects, as opposed to programmatic or regulatory considerations related to crediting programs. There are multiple components, processes, and administrative requirements for a successful crediting program. Examples of such considerations include scale issues between modeled nutrient and sediment loadings and benefits of an individual restoration project, applicable credit area, tracking and accounting, and so forth.

The purpose of this project is to highlight the experiences that municipalities have had with the implementation of the stream restoration protocols across the Chesapeake Bay Watershed at the state and local municipality level, as well as the feedback from states outside of the Chesapeake Bay watershed who have adopted or are considering adopting the WRF Guidance. This was accomplished through a review of stream restoration monitoring case studies, a review of stream restoration crediting and trading programs, and surveys of states and municipalities both inside and outside of the Chesapeake Bay watershed. The results of this project have yielded valuable information about the current and potential future use of the crediting protocols, including the need for protocol adaptability, establishment of crediting and trading programs, and the needs of potential users.

CHAPTER 2

Summary of Monitoring Studies and Stream Restoration Crediting and Trading Programs in the Chesapeake Bay Watershed

The WRF Stream Restoration Crediting Guidance includes the stream restoration crediting protocols approved by the CBP in 2014. Since that time, states and municipalities within the Chesapeake Bay watershed have been implementing the protocols to help meet their respective TMDL load reductions. This chapter provides a summary of monitoring studies, as well as a summary of crediting and trading programs within the watershed to highlight the experiences of the states and municipalities since the protocols have been implemented.

2.1 Monitoring Studies Within the Chesapeake Bay Watershed[1]

This project includes an examination of monitoring case studies within the Chesapeake Bay Watershed that can potentially be used to validate the stream restoration protocols in the WRF Stream Restoration Crediting Guidance and the CBP stream restoration protocols (Schueler and Stack 2014) which have been incorporated into the WRF Guidance. Monitoring studies for projects that have used the protocols were identified as part of the Stream Restoration Crediting Users Survey (Chapter 4), review of the literature and personal knowledge. It was the intention of the CBP Stream Restoration Expert Panel (Expert Panel) to incentivize monitoring to collect data needed to improve the protocols at some point in the future. Further, the Expert Panel recommended monitoring as the preferred method for determining sediment and nutrient credit for Protocol 1, the most widely used of the protocols. The parts of the protocols in need of verification are identified below. Note that these protocols were developed to estimate reductions in "edge of stream" erosion and pollution reduction attributed to stream restoration within the Chesapeake Bay Watershed Model, which does not account for losses/gains through transport. A sediment delivery factor was added to account for these losses after the initial protocols were developed. Also, under ideal circumstances, the studies used to validate the protocols should follow a well-designed quality assurance protection plan with an acceptable monitoring design (e.g., upstream/ downstream, before and after with a control). However, it is recognized that with tight monitoring budgets and competing needs that this might not be the case.

Verification needs of the stream restoration protocols:

- Default Rate – The monitoring approach could include before and after sediment and nutrient reductions per length of stream. This could include the use stream cross sections, bank pins, and sediment nutrient concentrations measurements. Other methods include before and after water column monitoring, and the use of drones and Lidar to estimate erosion rates. The protocols identify other methods to validate the BANCS method such as aerial photographs that can be used to estimate historical erosion rates, and dendro-geomorphic studies of exposed roots and new shoots.
- Protocol 1 – The monitoring approach could be similar to those identified above however the data

[1] **Note that during the review period of this document, a study from North Carolina Sea Grant and North Carolina State University was added to this section because the results may be extremely useful in evaluating the CBP stream restoration protocols.**

would be used to verify the Bank and Nonpoint Source Consequences of Sediment (BANCS) method which is predominantly used for Protocol 1. Further, the data can be used to verify the assumed stream restoration efficiency of 50%.

- Protocol 2 – The simplest monitoring approach to validate protocol 2 could be a before and after upstream-downstream monitoring design where nitrate samples are collected and compared during baseflow conditions. More advanced studies could require sophisticated research-grade monitoring which could include the installation of monitoring wells similar to the study that was used to develop the protocols (Kaushal et al. 2008; Striz and Mayer 2008).
- Protocol 3 – The monitoring approach could also use an upstream down-stream, before and after monitoring design. The complicating factor in this type of monitoring study is that sediment and nutrient loadings would be the measurement parameter. Studies of this nature could take several years to account for ambient variability and involve the establishment of flow gauging stations and wet-weather monitoring.

After review of the case studies, it was difficult to find statistically robust monitoring studies that included upstream-downstream and before and after paired watershed monitoring designs because they are expensive, take time and training. Funding options are limited as the Chesapeake Bay Trust is the only source of grant funding within the Chesapeake Bay watershed that will pay for statistically robust monitoring designs through their Restoration Grant Program (https://cbtrust.org/grants/restoration-research/). Further, since the protocols were developed in 2014, there has been insufficient time for organizations to mobilize and collect monitoring data that would provide statistically meaningful results. Most of the studies identified addressed only certain questions (e.g., Frederick County, MD and District of Columbia) that would improve the amount of sediment and nutrient load reduction credit they would receive and were not specifically designed to test the accuracy of the protocols except for the 50% restoration efficiency for Protocol 1. Table 2-1 provides a summary of the stream restoration monitoring studies within the Chesapeake Bay watershed.

Table 2-1. Stream Restoration Monitoring Studies Within the Chesapeake Bay Watershed.

Year	Organization and Primary Contact	Project Title	Project Description
2008-2014	Anne Arundel County Government/ University of Maryland Center for Environmental Science Janis Markusic Drs. Michael Williams and Solange Filoso	Monitoring the Effectiveness of Stormwater Treatment Practices at Reducing Pollutant Loads to Receiving Waters in the Magothy Watershed (Williams and Filoso 2014)	The main objectives of this project were to measure solute concentrations and discharge to estimate solute fluxes from Cypress and Dividing Creeks in Anne Arundel County, Maryland before and after implementation of stormwater best management practices (BMPs) in the watersheds. In the North Branch of the Cypress Creek subwatershed, the BMPs monitored included a bioretention at a Park & Ride site located on Arundel Beach Rd., and a hybrid wetland stream restoration complex with elements of Regenerative Stormwater Conveyances (RSCs). The stream and wetland restoration utilized a suite of techniques to restore a highly degraded channel approximately 3,000 feet in length and was constructed in 2012-2013. The design included the creation of headwater wetlands, transitions to anastomosed braided channels then a single thread channel, floodplain reconnection through use of low profile valley wide grade controls, creation of sand seepage wetlands in lower order tributaries, and natural channel design. Converting the Cypress Creek estimates (not including BMP reductions) into pollutant reductions per length of reconfigured stream reach (assuming a length of 0.4734 miles), values are 1141 lbs TN mi-1 yr-1 and 34.7 tons TSS mi-1 yr-1.
2016-2019	University of Maryland Center for Environmental Science Dr. Solange Filoso	Evaluating the Effectiveness and Sustainability of Novel Stream Restoration Designs for Coastal Plain Streams in Maryland: Integrating Existing and New Data from Stream Restoration Monitoring	This study will synthesize an extensive hydrochemical database from stream restoration sites in MD and DC to answer key questions pertaining to restoration effectiveness, sustainability, and ecological habitat condition. Stream restoration types include regenerative stream conveyance, step-pool conveyances, and valley restorations/stream-wetland complexes. The primary focus is to determine the impact of different stream restoration approaches on nutrient and sediment loads. The researchers hypothesize that results will be highly variable among restoration techniques, but that most designs will result in quantifiable reductions in nutrient loads.
2016-2020	Towson University Dr. Vanessa Beauchamp	Determining the Effects of Legacy Sediment Removal and Floodplain Reconnection on Ecosystem Function and Nutrient Export	This study will determine the efficacy of four legacy sediment removal and floodplain reconnection projects that range in impervious cover and vary in length by a factor of 4.5. Legacy sediment removal and floodplain reconnection projects decrease floodplain elevations and increase groundwater levels, potentially increasing nitrogen cycling and habitat for native wetland plant species and decreasing erosion of phosphorus laden sediments. By sampling within longer projects at several locations, the relationship between project length and degree of mitigation can be determined and whether this relationship varies with the amount of impervious surface in the watershed.
2016-2019	Carroll County Government/Center for Watershed Protection Ms. Gale J. Engles	The Self-Recovery of Stream Channel Stability in Urban Watersheds due to BMP Implementation	This is a paired-watershed study to evaluate the effectiveness of BMPs on stream channel protection. The research will evaluate the hydrogeomorphic response of BMP implementation in headwater stream drainage areas to determine if reductions in stream energy facilitate self-recovery of stream channel stability. Results will inform recommendations to credit BMPs as a hydrogeomorphic stream stabilization technique for sediment reductions as part of the Bay TMDL. It is expected that implementation of BMPs will reduce excessive stream channel and bed erosion by reducing stream energy resulting in the cessation of erosive flows that lead to the self-recovery of channel stability.

<table>
<tr><th>Year</th><th>Organization and Primary Contact</th><th>Project Title</th><th>Project Description</th></tr>
<tr><td>2015-2018</td><td>Smithsonian Environmental Research Center

Dr. Thomas Jordan</td><td>Evaluating the Performance of Regenerative Stormwater Conveyances in Urban Versus Rural Watersheds</td><td>This study is measuring the removal of nutrients and suspended sediments by RSCs and relating removal efficiencies to impervious surface in the watershed and the rate and variability of water inflow. Continuous monitoring and automated sampling is being used to measure RSC performance under a range of flow conditions in watersheds with contrasting impervious cover. The hypothesis is that RSCs reduce flow variability and remove nutrients and suspended sediments with decreasing efficiency as inflow rate and variability increase. Groundwater studies at one RSC will investigate sources of dissolved iron and transfers of nutrients from surface to groundwater flow. The results of this project should be available later in 2018.</td></tr>
<tr><td>2016</td><td>Stantec, Inc.

Josh Running</td><td>Stream Restoration as a Nutrient Reduction Practice:
A Test Case of Field-Measured Results vs. Predictive Erosion Rates Using Chesapeake Bay Program Protocols</td><td>This is a self-funded study that compared the default rate for sediment and nutrient load reduction from the CBP Expert Panel report to estimates using the BANCS method from protocol 1 and a modified BANCS method which caps the maximum bank height. BANCS method erosion rate estimates were also compared to estimates from bank pins. Stream bank soil nutrient concentrations were analyzed from 16 different locations and found they can vary by over 1,000 times that of the default values used in the protocols. Note that these estimates used the bulk density measurement cited in the example problem in the Expert Panel Report. They indicated that most municipalities they have worked with were not aware that bulk density must be measured when using Protocol 1. The conclusions of the study are:

The modified BANCS method gives a more reasonable estimate than the un-modified version
Soil nutrient values are extremely variable and should be monitored at each site instead of using the default values
The default rate can severely under-predict the erosion rate estimates compared to the BANCS and bank pin methods
More monitoring is needed to calibrate regional bank erosion curves

<table>
<tr><td>#</td><td>Method Description</td><td>Notes</td><td>TP (lbs/yr)</td><td>TN (lbs/yr)</td><td>TSS (Tons/yr)</td></tr>
<tr><td>1</td><td>Default Removal Rate</td><td>Fixed rate</td><td>28.5</td><td>31.4</td><td>51.9</td></tr>
<tr><td>2</td><td>BANCS</td><td>15-23 Ft. Bank hts</td><td>1322</td><td>2871</td><td>2518</td></tr>
<tr><td>3</td><td>BANCS (modified)</td><td>10 ft maximum bank hts</td><td>551</td><td>1196</td><td>1049</td></tr>
<tr><td>4</td><td>Monitoring (bank pins@90%)</td><td>w/525 ppm TP (Default)</td><td>502</td><td>1090</td><td>956</td></tr>
<tr><td>5</td><td>Monitoring (bank pins @90%)</td><td>w/128 ppm TP (measured)</td><td>110</td><td>475</td><td>956</td></tr>
</table>

One of the research needs identified in the Chesapeake Bay Program Expert Panel report support for the development of regional stream bank erosion curves for the BANCS method using local stream bank erosion estimates throughout the watershed and a statistical analysis of their predicted results. This project is a collaboration between local governments in VA, Fairfax, U.S. Fish and Wildlife Service, VA Department of Environmental Quality, and others. Sixty-two bank toe pins were</td></tr>
</table>

Year	Organization and Primary Contact	Project Title	Project Description
			installed across 26 project sites in eastern Virginia to facilitate development of a regional stream bank erosion curve. Data analysis is currently underway and results are expected later in 2018.
2013-2018	University of Maryland Baltimore County Dr. Andrew Miller	Assessment of Stream Restoration Impacts on Urban Sediment Load and Comparison with TMDL Guidelines	This is a Chesapeake Bay Trust funded small paired- and nested-watershed study of sediment yields from a set of stream gage sites in Dead Run, Baltimore County, Maryland, one of which has a restoration site upstream. The project is designed to collect before and after restoration data and to compare the headwater site with the restoration with another headwater site with no restoration. Downstream trends are also being investigated to see if any impacts observed below the restoration could be detected with increasing watershed scale. Data are being compared to five years of prior sediment data for five gage sites. Results should be available later in 2018.
2009-ongoing	Pennsylvania Department of Environmental Protection, Franklin and Marshall College, USGS and others Jeff Hartranft, PADEP Dr. Dorothy Merritts, Franklin and Marshall College	Big Spring Run Natural Floodplain, Stream, and Riparian Wetland - Aquatic Resource Restoration Project Monitoring	This is a monitoring study to determine the physical, chemical and biological effects of a legacy sediment removal project in Big Spring Pennsylvania where approximately 23,000 tons of legacy sediments were removed in September-October of 2011. The post restoration stream and floodplain wetland were established at the original level of hydric soils and consists of small channels with small banks that frequently experience overbank flooding. After restoration, the sediment flux out of the restoration reach is much less than prior to restoration (decreased from 3-year pre-restoration average of 218 tons per year to 1-yr post restoration value of 109 tons per year). Additional years of monitoring are necessary to identify trends with time and to calculate long-term averages for comparison with longer term averages of pre-restoration data. A summary of data collected since the initial monitoring summary report was published in 2013 is expected in the summer of 2018.
2008-ongoing	Washington DC Department of Energy and Environment (DOEE) Josh Burch	DOEE Stream Restoration Project Monitoring	The DOEE contracted with the Metropolitan Council of Governments to monitor 5 stream restoration projects, including Linnean Park, Nash Run, Watts Branch, Milkhouse Ford, and Bingham Run. Two additional projects slated for stream restoration were completed in 2017 for Pope Branch and Broad Branch. Pre-restoration monitoring at these sites included a rapid channel stability assessment using RSAT, the establishment of stream cross-sections, a vegetative study of riparian vegetation baseflow chemical and temperature monitoring and in-stream biological monitoring. The stream cross section data will be used to improve the estimates of stream restoration efficiency and can be compared against estimates using the stream restoration protocols.
2017-ongoing	The CWP, Ecotone, Inc. and the MD Department of Natural Resources Bryan Seipp, CWP	Bar-T Stream Restoration Study	The Center is working with Ecotone, Inc and the MD Department of Natural Resources to study the nutrient reduction benefit of a 1,500 linear ft stream restoration project in Frederick County MD. An additional 2,225 linear ft of smaller side channels will also be restored, but are not part of this study. The project will help Frederick County meet its TMDL requirements under its Phase I MS4 permit. The study involves pre- and post-monitoring using Protocol 1 (BANCS method) which will then be compared to estimates made using monumented cross sections and bank pins. Thirty stream banks have been assessed using the BANCS method and 6 cross sections have been installed. The study is expected to end in 2020 with ongoing monitoring thereafter.
2018 - ongoing	CWP, EPR, Inc and the York County Planning Commission	York County Stream Restoration Crediting Study	The Center is working with EPR, Inc. and the York County, PA. Planning Commission to evaluate 19 potential stream restoration sites in south central Pennsylvania to determine the sediment and nutrient credit for meeting local and Chesapeake Bay TMDLs. The 19 sites were identified in a joint Pollution Reduction Strategy comprising 42 communities required to meet Phase II MS4

Year	Organization and Primary Contact	Project Title	Project Description
	Bryan Seipp, CWP		requirements. The total stream length is approximately 23,330 linear feet. This study will use the BANCS method under Protocol 1 of the stream restoration protocols to estimate nutrient and sediment load reductions. Further, 27 monumented cross sections and bank pins are being established for pre- and post-construction evaluation of stream restoration efficiency. The study is expected to end in 2018 with ongoing monitoring in the post construction period by others.
2018-2019	CWP, Water Science Institute Mike Hickman, CWP	Paxton Creek, PA Stream Restoration Crediting Study	Under a National Fish and Wildlife Foundation grant the Center is working with the Water Science Institute (http://www.waterscienceinstitute.org/) to use Lidar and drone technology to estimate stream bank erosion rates for targeting restoration projects at 3 locations in the Paxton Creek Watershed in the Harrisburg, PA area. The work will help to target stream restoration projects identified in the Pollution Reduction Plans that were developed to meet the joint Phase 2 MS4 permit for that region. The study includes two methodologies, both of which can be compared to erosion estimates using Protocol 1 of the Expert Panel Report. The first technique involves a differencing analysis for change detection between two Lidar datasets that will estimate erosion rates for the entire Paxton Creek watershed. For the second technique, three sites will be mapped with high-resolution digital elevation models (DEMs) produced from photogrammetry using a drone followed by a differencing analysis between the latest available 2014 Lidar flyover and the drone DEM. This will give a baseline of pre-restoration conditions for developing proposed TMDL reductions. Initial drone flights were conducted in May 2018 and the final study results will be available later in 2018.
2016 - ongoing	MDOT State Highway Administration Ryan Cole, SHA	MDOT SHA Stream Restoration Monitoring Project	The Maryland State Highways Administration (SHA) is conducting a comprehensive before and after, upstream - downstream monitoring effort of a 3,500-foot section of stream slated for construction. The monitoring is being done to partially fulfill monitoring requirements under their MS4 permit. Monitoring includes continuous flow gauging, dry and storm event sampling, geomorphic monitoring, and biological monitoring. The sampling includes bulk density analysis and stream bank sediment analysis for nutrients. Approximately a year and a half of pre-construction data has been collected. Monitoring will continue through the construction phase which is underway and will continue for at least 2 years after construction. Additionally, the United States Geological Survey (USGS) is conducting a photogrammetric analysis using drones to develop DEMs that can be compared to historic lidar data for estimating stream bank erosion. This comprehensive monitoring effort is being done to help collect data to improve the CBP stream restoration protocols and credits they receive in complying with the MS4 permit.
2011 - ongoing	KCI Technologies, Inc. and Howard County Dept. of Public Works	Howard County CBT Brampton Hills Study	In a project funded by the Chesapeake Bay Trust Program, KCI Technologies, Inc. in partnership with Howard County Department of Public Works conducted pre and post restoration monitoring at the Brampton Hills stream restoration site located in Ellicott City, MD. The goal of the study was to estimate the effectiveness of stream restoration in reducing total nitrogen, phosphorus, and total suspended sediments. The study's objective was to compare the results to the Chesapeake Bay Program's (CBP) Default Stream Restoration credit which the Maryland Department of the Environment has adopted for TMDL compliance as an alternative to the 3 protocols. The restoration included bed and bank stabilization efforts for approximately 3,165 linear feet of stream channel in addition to outfall stabilization. Water quality sampling occurred during baseflow and storm flow for

<table>
<tr><th>Year</th><th>Organization and Primary Contact</th><th>Project Title</th><th>Project Description</th></tr>
<tr><td></td><td></td><td></td><td>2 years prior to restoration (2010 – 2011) and 6 years post restoration (2012 – 2017). Monitoring is expected to continue indefinitely. The results are shown in the following Table.

<table>
<tr><td colspan="4">Comparison of CBP's Default rates with Brampton Hill Monitoring Results</td></tr>
<tr><td></td><td>TN lbs/lft/yr</td><td>TP lbs/lft/yr</td><td>TSS lbs/lft/yr</td></tr>
<tr><td>CBP Default Rate</td><td>0.075</td><td>0.068</td><td>247.5</td></tr>
<tr><td>Monitoring Results</td><td>0.20</td><td>0.20</td><td>74.9</td></tr>
<tr><td colspan="4">Note the TSS value does not include a sediment delivery factor (0.181 for non-coastal plain and 0.061 for coastal plain) which is required for TSS credit.</td></tr>
</table></td></tr>
<tr><td>2017-2018</td><td>North Carolina SeaGrant and North Carolina State University

Barbara Doll</td><td>Evaluation of Nutrient Reduction Crediting Strategies for Stream Restoration

(Doll et al. 2018)</td><td>North Carolina Sea Grant (NCSG) and North Carolina State University (NCSU) evaluated draft standards for awarding nutrient credits for stream restoration efforts developed by the North Carolina Division of Water Resources. The draft standards were based on the Chesapeake Bay Program (CBP) protocols developed by Schueler and Stack (2014). The evaluation consisted of testing the proposed nutrient credit calculation methods on four case study restoration projects to:
1) Determine the level of effort necessary to prepare nutrient credit estimates
2) Identify opportunities to address shortcomings and simplify the proposed credit standards
3) Where appropriate, develop modified nutrient credit standards for improving application and accuracy of reduction estimates.
Four case studies were used to evaluate the 3 protocols (1. Credit for Prevented Sediment, 2. Credit for Denitrification in Hyporheic Zone and 3. Credit for Floodplain Reconnection). The results showed that Protocol 1 provided the greatest nutrient removal credit and the prevention of streambank erosion through stream restoration has the greatest impact on the prevention of nutrient introduction to downstream waters. The CBP protocol default values for nutrients were higher (25% TN and 78% TP) than literature values of concentrations found throughout North Carolina. Therefore, the use of localized nutrient data is recommended.

The CBP Protocol 2 applies a default denitrification rate to a theoretical “box” of soil beneath the stream bed extending into the floodplain for the length of the restored stream reach. This study found that the default dimensions overestimated the volume of the box because of confining layers below the riffles. As a result, the nitrogen reduction benefit in the 3 case study streams studied were reduced on average by over 1/3 compared to the reductions using the CBP Protocol. Before and after restoration baseflow monitoring at two case study sites found conflicting results most likely due to the short monitoring period.

The CBP Protocol 3 was found to be labor intensive and resulted in very small treatment efficiencies that were in the lower end of the efficiency curves developed by CBP requiring interpolation. Revised treatment efficiency curves were developed using flow frequency analysis from 5 USGS gauged streams. The new curves were developed with a higher resolution than those developed by</td></tr>
</table>

Year	Organization and Primary Contact	Project Title	Project Description
			the CBP, however the sediment and nutrient reduction benefits were comparable to the CBP protocol. Potential revisions to the CBP include (1) retaining CBP Protocol 1 with NC specific streambank concentrations and combining CBP 2 and 3 to calculate an aerial denitrification rate partitioned by streambed area and floodplain area using the a median denitrification rate for streams and riparian zones based on a comprehensive study by (Lammers and Bledsoe, 2017); or (2) allowing credit solely based on the CBP Protocol 1 with NC specific streambank concentrations.

Studies that involve monitoring to test or enhance the accuracy of the protocols include the York County and Paxton Creek stream restoration crediting studies in Pennsylvania, the stream restoration case study and development of regional erosion rate curves in Virginia, the assessment of stream restoration impacts on urban sediment load and comparison with TMDL guidelines in Maryland, the MD SHA stream restoration monitoring project, the Howard County CBT funded Brampton Hills Study, and the NC evaluation of nutrient reduction and crediting strategies. York County, PA, who manages a joint MS4 consortium of 42 Phase 2 MS4s, initiated a study led by the Center for Watershed Protection (CWP) and Ecosystem Planning & Restoration, Inc. (EPR) to improve the accuracy of the BANCS method (Protocol 1) by collecting data to help develop a regional erosion rate curve to be used with the BANCS method. This includes the establishment of bank pins and monumented cross-sections which will be monitored pre- and post-construction to get better estimates of stream restoration efficiency. CWP is also working on a National Fish and Wildlife funded study with the Water Science Institute (http://www.waterscienceinstitute.org/) for the Harrisburg Capital Region Council of Governments which represents several Phase 2 permittees specifically to validate the BANCS method using two approaches. The first includes a differencing analysis for change detection between two Lidar sets that will estimate erosion rates for the entire Paxton Creek watershed. For the second approach, three sites will be mapped with high-resolution DEMs (of stream channels) produced from photogrammetry using a drone followed by a differencing analysis between a 2014 Lidar flyover and the drone DEM to estimate erosion rates.

Stantec conducted a study in 2016 for a stream in northern Virginia that compared the default rate for sediment and nutrient load reduction from the CBP Expert Panel report to estimates using BANCS from protocol 1 and monitored bank pins (Stantec 2017). They found that the BANCS method using the NC regional curve and bank pins resulted in higher nutrient and sediment load reductions than the default rate. The BANCS method severely overestimated the load reductions in comparison to the default rate and monitoring data due to the high 12-24-foot bank heights at the study site. A revised BANCS method that capped the bank height at 10 feet provided estimates that aligned better with the bank pin monitoring data. This study also supported the need for local bank erosion rate curves as part of the BANCS method. Selection between the NC and Hickey Run curves yielded results that were up to 4 times different from one another. In 2015, Stantec, initiated a self-funded effort to facilitate development of a regional stream bank erosion curve for use with the BANCS method. Stantec reached out and received in-kind support from local governments in VA, Fairfax, U.S. Fish and Wildlife Service, VA Department of Environmental Quality, and the USGS. The idea was that each organization would share their own BANCS data for the development of the regional curve. This effort is expected to be completed later this year.

KCI Technologies, Inc in partnership with Howard County Department of Public Works conducted a study funded by the Chesapeake Bay Trust Program for pre and post restoration monitoring at the Brampton Hills stream restoration site located in Ellicott City, MD. The goal of the study was to estimate the effectiveness of stream restoration in reducing total nitrogen, phosphorus, and total suspended sediments. The results of the pre and post restoration loading calculations suggest the stream restoration effort led to a considerable reduction of nutrients and suspended solids being generated from within the study area. Estimated nutrient reduction rates per linear foot of restoration appear to be markedly higher at Brampton Hills as compared to the revised CBP's default removal rates. Results from six years of post-restoration monitoring (2012-2017) indicate nutrient removal rates of approximately 0.20 lbs/ft total nitrogen (TN) and 0.20 lbs/ft total phosphorus (TP) compared to the CBP's Default rates of 0.075 lbs/ft TN and 0.068 lbs/ft TP. The estimated total suspended solids (TSS) reduction rate at Brampton Hills of approximately 74.9 lbs/ft is higher than CBP default rate of 44.9 lbs/ft however when applying a default sediment delivery loss factor (0.18) it is much lower at 13.5 lbs/ft.

North Carolina Sea Grant (NCSG) and North Carolina State University (NCSU) evaluated draft standards for awarding nutrient credits for stream restoration efforts developed by the North Carolina Division of Water Resources based on the stream restoration protocols (Doll et al. 2018). The results showed that Protocol 1 provided the greatest nutrient removal credit and that the default dimensions of the theoretical hyporheic box used in Protocol 2 overestimated the volume of the box because of confining layers found below riffles. Protocol 3 was found to be labor intensive and resulted in very small treatment efficiencies. Potential revisions to the stream restoration protocols to adjust for use in NC include (1) retaining Protocol 1 with NC specific streambank concentrations and combining Protocols 2 and 3 to calculate an areal denitrification rate partitioned by streambed area and floodplain area using the a median denitrification rate for streams and riparian zones based on a comprehensive study by (Lammers and Bledsoe, 2017); or (2) allowing credit solely based on Protocol 1 with NC specific streambank concentrations.

The MD SHA Office of Environmental Design is conducting a comprehensive before and after, upstream - downstream monitoring effort of a 3,500-foot section of stream slated for construction on Little Catoctin Creek in Frederick, Maryland. The monitoring is being done to partially fulfill monitoring requirements under their MS4 permit. Monitoring includes continuous flow gauging, dry and storm event sediment and chemistry sampling, geomorphic monitoring, and biological monitoring. The sampling includes bulk density analysis and stream bank sediment analysis for nutrients. Approximately a year and a half of pre-construction data has been collected. Monitoring will continue through the construction phase which is underway and will continue for at least 2 years after construction. Additionally, the USGS is conducting a photogrammetric analysis using drones to develop DEMs that can be compared to historical lidar for estimating stream bank erosion. This comprehensive monitoring effort is being done in part, to help collect data to improve the stream restoration protocols that they use for crediting under their MS4 permit.

Several studies were identified that while not specifically designed to validate the protocols should have results that can be used for this purpose. The studies conducted by Anne Arundel County, University of Maryland Center for Environmental Science, Towson University, Smithsonian Environmental Research Center, Pennsylvania Department of Environmental Protection, Washington DC Department of Energy and Environment and MD SHA focus on nutrient and sediment load reductions of stream restoration projects measured through either monitoring or the BANCS method. These load reductions can be compared to the default rate from the CBP Expert Panel report. In addition, they can be evaluated to determine if there are any trends in load reduction among the various stream restoration techniques and monitoring/modeling approaches. The Carroll County stream channel stability project is unique in that it focuses on the hydrogeomorphic response of BMP implementation in headwater stream drainage areas to determine if reductions in stream energy facilitate self-recovery of stream channel stability. This is not a practice currently included in either the CBP Expert Panel report or the WRF Stream Restoration Guidance. However, the results of the Carroll County study will help to determine if stream channel recovery due to watershed BMP implementation is a feasible practice for future crediting approaches.

Many of the monitoring studies have shown the importance of using site-specific monitored values for stream bank soil nutrient concentrations, which can vary widely depending on soil type, geology, vegetation, historical land use, soil applications, and other factors. Nutrient concentrations have a large impact on the calculated load reduction estimates. For example, if site-specific concentrations are found to be half of the default value, the resulting load reductions calculated would also be reduced by half. The default values in the CBP Expert Panel report are 2.28 lb/ton TN and 1.05 lb/ton TP based on a study by Walter et al. (2007). Stantec developed a Technical Memorandum (Beisch and Foraste 2013) in 2013 evaluating nutrient concentrations in stream bank soils from 16 projects in tidewater and northern

Virginia and found average nutrient concentrations that were less than half of the default values in the CBP Expert Panel report. Similarly, monitored stream bank nutrient concentrations for a restoration project at the James Madison University in Virginia found lower concentrations than the default values (Mumaw 2015). An example project Stantec conducted in Virginia to show comparison of field-measured results to predictive erosion rates using Chesapeake Bay Program Expert Panel protocols shows the variability in concentrations depending on sampling locations. Wooded areas of a stream restoration site were found to have lower stream bank soil concentrations than agricultural fields on that same site. Table 2-2 provides the soil nutrient concentrations from monitoring studies in comparison to the CBP Expert Panel Report default values.

Table 2-2. Streambank Soil Nutrient Concentrations.

	TN (lb/ton sediment)	TP (lb/ton sediment)
CBP Expert Panel Report Default (Schueler and Stack 2014)	2.28	1.05
Average from 16 Projects in Virginia (124 total samples) (Stantec 2013)	Range: 0.06 – 3.12[1] Average: 0.62	Range: 0.02-4.24 Average: 0.33
Example Project in Virginia (Stantec 2017)	Wooded: 2.69 Field: 4.0	Wooded: 0.63 Field: 2.5
James Madison University Arboretum, Virginia (Mumaw 2015)	0.75 - 1.32	0.1 - 0.75
Average from 4 Case Study Projects in North Carolina (Doll et al. 2018)	Range: 1.01 – 1.75 Average: 1.34	Range: 0.41 – 0.86 Average: 0.65

[1]*Measured as Total Kjeldahl Nitrogen (TKN).*

Bulk density is also an important factor that has a large impact on the calculated nutrient and sediment load reductions. The CBP Expert Panel report provided a bulk density value of 125 lbs/ft^3 as part of an example case study that has in some cases been erroneously used as a default value. This example value is a high estimate compared to what has been shown through some of the monitoring studies and if used as a default would generate higher nutrient and sediment load reductions than site-specific data. The WRF Stream Restoration Crediting Guidance does not include this example bulk density value as part of a case study and therefore doesn't have the risk of an assumed bulk density default. The WRF Guidance states that soil bulk densities may be measured in the field or obtained from the U.S. Department of Agriculture Soil Survey. Table 2-3 provides the streambank soil bulk density from monitoring studies in comparison to the CBP Expert Panel Report case study example.

Table 2-3. Streambank Soil Bulk Density.

	Bulk Density (lbs/ft^3)
CBP Expert Panel Report Case Study Example (Schueler and Stack 2014)	125
Carroll County Self Recovery of Stream Channel Stability Project Average of 5 sites and 39 samples	56
James Madison University Arboretum, Virginia (Mumaw 2015)	80
Paxton Creek, PA Stream Restoration Crediting Study Bulk density range of 9 samples	67 - 76
Case Study Projects in North Carolina (Doll et al. 2018)	52 - 88

2.2 Stream Restoration Crediting and Trading Programs Within the Chesapeake Bay Watershed

Stream restoration projects may provide pollutant trading and mitigation opportunities where water quality regulatory programs require pollutant reduction within a watershed. Environmental crediting concepts have been developed and are continually evolving via state and federal water quality trading policies and programs and as part of stream and wetland related mitigation under Section 404 of the Clean Water Act. Water quality trading has focused on both point sources (e.g., wastewater treatment) and non-point sources (e.g., agriculture), but increased nutrient loading and decreased nutrient processing in degraded stream systems have not been recognized and included. However, stream restoration is an increasingly common practice that can influence water quality in degraded systems.

The Chesapeake Bay Program approved the three protocols and the Default rate described in Section 2.1 for crediting purposes that would allow all states within the Chesapeake Bay Watershed to receive sediment and nutrient reduction credits for meeting their TMDL wasteload allocations. The use of these protocols is widespread among utilities and MS4 jurisdictions within these states and has been since their approval in September 2014. Programs that would allow trading within different source sectors for the states of Maryland, Pennsylvania, and Virginia are reviewed and summarized in the following sections.

2.2.1 Maryland

The Maryland Departments of Agriculture (MDA) and the Environment (MDE) have been working collaboratively to establish a voluntary, market-based program to promote the use of trading as a viable option for achieving the State's sediment and nutrient reduction goals. This program envisions trading not only between sectors ("cross-sector trading") within Maryland, but ultimately between Maryland and the other Bay states ("interstate trading").

Maryland's Nutrient Trading Program is a public marketplace for the buying and selling of nutrient (nitrogen and phosphorous) credits. The purpose of the Program ranges from being able to offset new or increased discharges to establishing economic incentives for reductions from all sources within a watershed and achieving greater environmental benefits than through existing regulatory programs. To facilitate trading, a web-based Calculation Tool, Marketplace and Trading Registry were established. The Calculation Tool assesses credit generating capacity while the Market Place and Trading Registry record approved credits and transactions and provide a means for the public to track the progress of Maryland's trading program (http://www.mdnutrienttrading.com/).

Draft Regulations were published December 8, 2017 (MDE 2017a) that would include trading between the MS4s and other source sectors (NPDES Point source and Agricultural NPS). Several stakeholders (e.g., MS4s, NGOs, trade organizations) provided comments which are currently being addressed. Draft Trading Guidance was also developed and is being modified to address comments (MDE 2017b). The guidance includes a method previously developed by MDE as part of their Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated guidance for NPDES Stormwater Permits and relates the reduction in pollutant loads from new and alternative treatment practices into an equivalent impervious acreage which includes stream restoration (MDE 2014). This is a separate crediting method for relating stream restoration to impervious cover equivalency for purposes of calculating progress towards meeting the MS4 permit requirement to restore 20% of a jurisdiction's impervious surface area that has little or no stormwater management. Note that the 2014 MDE guidance does include the CBP stream restoration crediting protocols for purposes of calculating progress toward meeting stormwater wasteload allocations for TMDL compliance, however, they are not currently incorporated into equivalent impervious calculation. MDE is planning on updating the crediting method to align with the CBP stream restoration protocols later this year.

The impervious area equivalent method is based on the difference in pollutant load, or the Delta, between one acre of urban impervious runoff and one acre of forested runoff. The MS4 permittee must acquire the equivalent number of credits for all sediment, nitrogen and phosphorus to count toward one impervious acre of restoration but may acquire credits from multiple sellers and practices, either individually or through an aggregator or broker. MDE has indicated that the crediting method will likely be changed to align with the protocols developed for the Chesapeake Bay and expects to finalize the Trading Program by the Fall of 2018.

2.2.2 Virginia

Article 4.02 of the Code of Virginia established the Chesapeake Bay Watershed Nutrient Credit Exchange Program in 2005 and provides Virginia's point and nonpoint sources in the Bay watershed with the opportunity to meet required nutrient reductions through trading. The legislation also allows point sources to purchase nutrient reductions from nonpoint sources to offset new or increased nutrient discharges in excess of established load caps. In addition, this legislation directed the Virginia Department of Environmental Quality (VA DEQ) to develop and issue a watershed general permit for significant point source discharges of nutrients to the Bay and its tributaries. The General Virginia Pollutant Discharge Elimination System Watershed Permit Regulation for Total Nitrogen and Total Phosphorus Discharges and Nutrient Trading in the Chesapeake Watershed in Virginia (9 VAC 25-820-10 et seq.), approved in 2006, defines new and expanded nutrient discharges and specifies how permitted facilities can offset new or expanded nutrient discharges to the Bay. (http://www.deq.virginia.gov/Programs/Water/PermittingCompliance/PollutionDischargeElimination/NutrientTrading.aspx)

The watershed general permit requires that trading partners do the following (VA DEQ 2008):

- Determine offsets using a ratio of two pounds reduced by nonpoint BMP enhancements for each additional pound discharged.
- Generate and apply offsets to an offset obligation in the same calendar year in which the discharge occurs.
- Generate and apply offsets in the same tributary.
- Demonstrate that offsets achieve nutrient reductions beyond those already required by or funded under federal or state law or by the Virginia tributaries strategies plans.
- Calculate offsets using BMP efficiency rates and attenuation rates, as established by the latest science and relevant technical information, and approved by VA DEQ.
- Base offsets on appropriate delivery factors, as established by the latest science and relevant technical information, and approved by VA DEQ.

In 2010, Virginia's Phase I WIP for the Chesapeake Bay TMDL recommended expanding the nutrient credit exchange program to include all source sectors (Commonwealth of Virginia 2012). Since then, the state drafted and passed legislation for an expanded nutrient credit exchange program. The nutrient and sediment load reduction values assigned to nonpoint source practices are consistent with the efficiency and nutrient load reduction values assigned by the CBP at the time of credit certification. Therefore, any stream restoration projects credited as part of Virginia's nutrient credit exchange program since 2014 would follow the CBP stream restoration crediting protocols.

In addition, all point sources acquiring waste load allocations (WLA) from nonpoint source BMPs must secure 2 lbs. of reduction for every 1 lb. of point source WLA (2:1 trading ratio). Trading ratios for other situations will be determined on a case-by-case basis. New WLAs for new/expanding sources are called offsets (since it "offsets" new load) and the offset must be maintained as long as the new nutrient loads occur. Offsets, like existing point source compliance credits, cannot be traded across the four major Virginia river basins. The statute also allows nonpoint source offsets to be acquired through public or private entity acting on behalf of the landowner but any offset activity must be included in the point source facilities individual permit (§62.1-44.19:15.B.1b).

The statute also outlines nonpoint source baseline requirements that must be achieved before granting nonpoint source offsets. Under the Virginia law, nonpoint source offsets are reductions in nutrient loads above and beyond reductions required by state law or by reductions already identified in nutrient/sediment reduction plans, called the "tributary strategies" (§62.1-44.19:15.B.1b).

As of March 2017, there have been six applications for stream restoration to Virginia's nonpoint source nutrient bank.
(http://www.deq.virginia.gov/Portals/0/DEQ/Water/PollutionDischargeElimination/NPS%20Trading/NPSCreditApplications.pdf?ver=2017-03-10-133931-920).

There is currently only one stream restoration project to date listed in Virginia's Nonpoint Source Nutrient Credit Registry.
(http://www.deq.virginia.gov/Portals/0/DEQ/Water/PollutionDischargeElimination/NPS%20Trading/NonpointCreditRegistry.xlsx?ver=2017-07-18-105253-973)

2.2.3 Pennsylvania

The primary purpose of Pennsylvania's Nutrient Trading Program is to provide a more cost-efficient way for National Pollutant Discharge Elimination System (NPDES) permittees in the Chesapeake Bay Watershed to meet their effluent cap load limits for nutrients. The program was established in 2010 and is one of the first in the country to have both agricultural operations (nonpoint sources) and wastewater treatment facilities (point sources) participating in a nutrient credit trading program (http://www.dep.pa.gov/Business/Water/CleanWater/NutrientTrading/Pages/default.aspx) however it has not been designed to included MS4s or the urban sector. The program is voluntary and follows these principles:

- A trade must involve comparable credits (for example, nitrogen may only be traded for nitrogen) that are expressed as mass per unit time (pounds per year).
- Credits generated by trading cannot be used to comply with existing technology-based effluent limits except as expressly authorized by regulation.
- Trading may only occur in a Pennsylvania Department of Environmental Protection (PA DEP) defined watershed.
- Trading may take place between any combination of eligible point sources, non- point sources and third-party aggregators.
- Each trading entity must meet applicable eligibility criteria established under the Nutrient Trading Program regulations, 25 Pa. Code Section 96.8.

Although stream restoration is listed as both an urban and non-urban BMP under the program's BMP descriptions, only agricultural nonpoint sources are currently approved for crediting. The credited load reductions are the previously approved pounds per linear foot CBP stream restoration credits (Table 2-4) before the CBP Stream Restoration Expert Panel protocols were approved in 2014.

Table 2-4. Stream Restoration Nutrient and Sediment Reductions included in Pennsylvania's Nutrient Trading Program Nonpoint Source Calculation Spreadsheets.

	TN Reduction (lbs/ft)	TP Reduction (lbs/ft)	TSS Reduction (lbs/ft)
Stream Restoration on Conventional Till and Pasture	0.026	0.0046	3.32
Stream Restoration on Conservation Till, Hay	0.02	0.0035	2.55

A listing of nonpoint source credit generators and pollutant reduction strategies used as of March 2018 shows that stream restoration has not yet been used to generate credits. (http://files.dep.state.pa.us/Water/BPNPSM/NutrientTrading/NutrientCreditRegistry/NPS_Generators.pdf).

According to the Pennsylvania Department of Environmental Protection (PA DEP 2017a), there are two Phase 1 MS4 permits and 953 Phase 2 permits. Unless granted a waiver, MS4 communities with TMDLs must submit individual or regional Pollution Reduction Plans. For those municipalities within the Chesapeake Bay Watershed, stream restoration projects must follow the Chesapeake Bay Program Expert Panel protocols (PA DEP 2017a). If existing sediment loads were calculated using modeling at a local watershed scale, the default rate to be used is 115 lb/ft/yr which is a convergence of MapShed modeled streambank erosion loads from a group of urbanized watersheds, the 248 lb/ft default edge of field (EOF) rate in the CBP Stream Restoration Expert Panel Report with the 50% efficiency uncertainty factor specified for the Protocols, and field data collected following the BANCS methodology where projects have been implemented and load reductions calculated using the Protocols. Alternately, sediment reduction from streambank restoration projects when existing loads are calculated using modeling at a local scale may be estimated using the Expert Panel Protocols of the report and must then apply the 50% efficiency uncertainty factor.

Although Pennsylvania does not currently have a trading program for MS4s, PA DEP has provided guidance to Phase II MS4s that would allow for offsets (PA DEP 2017b). A MS4 may propose stormwater pollutant reduction BMPs outside of the TMDL and/or PRP Planning Area for possible approval as offsets toward meeting TMDL and/or Pollution Reduction Plan (PRP) load reduction requirements. Unless approved otherwise by PA DEP, such projects must be located within the jurisdiction that developed the TMDL Plan and/or PRP, and treat or manage stormwater that would drain to the impaired waters of interest under a TMDL Plan or PRP. In all cases where offsets are proposed, an individual permit is required. Examples of projects where offsets may be approved by PA DEP include but are not limited to a reduction of impervious areas outside of the Planning Area and BMPs at agricultural operations that are outside of the planning area but within the drainage area of the impaired waters of interest. PA DEP may grant offsets for the amount (lbs) of pollutants expected to be reduced after baseline and regulatory requirements are met. For the purpose of TMDL Plans and PRPs, baseline requirements are, in general, load reduction requirements established in TMDLs for sectors that do not require NPDES permits. For example, if a TMDL specifies that a sediment load reduction of 80% is necessary from the unregulated or non-urban stormwater sector in order to meet water quality standards, PA DEP may approve offsets for a reduction in impervious area outside of the planning area for the amount (lbs) of sediment removed after the 80% reduction requirement is met. An operation and maintenance (O&M) plan as well as assurances for ongoing O&M must be submitted as an attachment to any TMDL Plan and/or PRP proposing the implementation of BMPs for offsets. Permittees must report actual O&M activities on Annual MS4 Status Reports to continue receiving approval for the use of offsets.

CHAPTER 3

Summary of the Scientific and Grey Literature of Strategies for Restoring Streams Through the Control of Watershed Processes and Channel Reconfiguration

WRF defined "watershed processes" as being actions taken throughout a watershed but outside of the stream corridor itself to mitigate the damaging effects of land use change or other disturbances such as stormwater retention or detention ponds. While controlling watershed processes prior to degradation of the stream intuitively makes sense, it was not specifically included in the WRF stream restoration crediting guidance because of the limited quantifiable evidence on its effect on stream processes. Likewise, restoring streams through channel reconfiguration was not incorporated into the WRF crediting guidance. Channel reconfiguration is typically associated with other stream restoration techniques, making it difficult to isolate the pollutant removal benefits of channel changes alone. This literature review was conducted by searching peer-reviewed journal articles and white papers to identify both modeling and monitoring studies that investigated channel reconfiguration and the control of watershed processes. It builds upon a previous literature review by Lammers (2015) that was conducted to support development of the WRF stream restoration crediting guidance. All publication years were considered for the review, even those conducted prior to the Lammers (2015) review, in order to gather the largest amount of resources possible. The purpose of this literature review was to determine if enough information exists to gain a better understanding of the benefits and limitations of channel reconfiguration and the control of watershed processes such that they can be incorporated into the WRF crediting guidance.

3.1 Control of Watershed Processes

National stormwater management regulations are relatively new, occurring as a result of EPA's Stormwater Rule in 1990 which later led to the MS4 permit program (U.S. EPA 1990). Some states initiated stormwater management regulations much earlier, such as Maryland, (MDE 2012) who began their program in 1983. Stormwater programs initially focused on new development and water quantity and evolved to include water quality controls and retrofitting the built environment.

Decades of research have improved the scientific understanding of urban hydrology and stream processes, including hydraulics, that have informed the way stormwater is regulated and managed. This scientific-based understanding of stormwater runoff, its quality, quantity and downstream impacts, has advanced the innovative design of best management practices (BMPs) to better protect water resources. These BMPs have been found to be a cost-competitive alternative to stream restoration in even the least favorable settings, such as a fully developed watershed with no existing detention (Hawley et al. 2012). However, the capacity of upland BMPs to affect stream energy dynamics that reduce erosive flows causing channel instability remains a needed area of research.

Despite decades of BMP implementation, the continued degradation of streams remains a concern (Hawley et al. 2013; Loperfido et al. 2014; Walsh et al. 2016). The full recovery of a stream due to BMP implementation is a complex process, that despite expected water quality improvement at the site-scale, the long-term and full restoration of stream health may be hampered by lag effects (Lyerly et al. 2014), extent and type of practice implemented, as well as incomplete identification or inadequate treatment of the causes of degradation (Palmer et al. 2014). Although the specific causes of degradation are site, or watershed specific, research findings consistently find altered hydrology within the drainage area due to urbanization is a major cause of stream erosion leading to degraded stream water quality and biology (e.g., Paul and Meyer 2001; Schueler et al. 2009).

A majority of the existing literature focuses on the hydrologic benefits (i.e., reduction of peak discharge, volume reduction) of BMPs. A literature review by Jefferson et al. (2017) of stormwater management effectiveness at the watershed scale found that studies of peak flows and flow volumes are common, whereas baseflow, groundwater recharge, and evapotranspiration have received comparatively little attention. For example, Pennino et al. (2016) conducted a regional study of green infrastructure impacts at the small watershed scale in Baltimore and Montgomery Counties in Maryland and found that small watersheds with more than 10% of their total area treated by green infrastructure had less flashy hydrology, with 44% lower peak runoff, 26% less frequent runoff events, and 26% less variable runoff. Similarly, a study by Fleischmann (2014) of 12 stream sites in Hartfort, CT found that a 5% impervious cover reduction in the watershed decreased runoff by up to 16% for the 1-yr event. For a 30% impervious cover reduction, the runoff decreases by 68 to 88%. Aulenbach et al. (2017) found that for every 1% increase in watershed effective impervious area (EIA), the required increase in EIA treated by BMPs to counteract the effects of increased peak streamflow, stormwater yield, and storm streamflow runoff ranged from 1.1% to 2.6%.

More and more stormwater management programs driven by MS4 permits have incorporated storm water management design standards that use green infrastructure to mimic a more natural hydrologic regime (Schueler and Lane 2012) to reduce impacts to receiving streams and enhance the potential for restoration to be successful. One of the most important aspects to effective implementation of these practices is a routine long-term maintenance plan. In proposing design objectives for stream protection, Perrin et al. (2009) speculated that “if the predevelopment volumes of runoff are mimicked, then other water quantity goals such as stream stability outflows and one-year, 24-hour storm peak mitigation are assumed to be met.” A modeling study of a small catchment in Colorado (Bledsoe 2002) found a two-year stormwater peak control detention facility would need its storage volume increased by 61% to adequately protect the stream channel. Research is necessary to determine whether these approaches deliver the desired results. While numerous studies evaluate the hydrologic benefits of BMPs at the site-scale, limited field data are available to evaluate the effect of BMP implementation on the stream channel itself. That is, the hydrogeomorphic response attributed to BMPs is less well-known in regard to the degree they can mitigate flows that contribute to excessive stream bed and bank erosion.

Table 3-1 provides a summary of the watershed process studies included in the Lammers (2015) literature review, as well as additional studies identified as part of this review.

Table 3-1. Summary of Watershed Process Studies Included in the Lammers (2015) Literature Review and New Studies Identified as Part of this Review.

Watershed Process Studies Included in Lammers (2015) Literature Review	
Study	**Key Findings**
Charbonneau and Resh 1992	Improved water quality and recovery of the stream ecosystem was largely due to concerted efforts to reduce pollutant loading to the stream.
Bergfur et al. 2012	Riparian buffers did not result in statistically significant improvements in water quality, but source control (i.e. removal of a septic system) resulted in measurable reductions in ammonium and phosphate concentrations.
Selvakumar et al. 2010	Failure of specific stream restoration projects to improve water quality on their own could be attributed to lack of stormwater controls to augment in-channel improvements.
Roni and Beechie 2013	Designs that explicitly account for contemporary fluxes of water, sediment, and nutrients, have a higher likelihood of meeting stability and water quality objectives.
Miller and Kochel 2009	Analog approaches to stream restoration sometimes focus almost exclusively on restoring form with instream structures of uncertain persistence, often without regard to the full range of water and sediment fluxes.
Violin et al. 2011	Analog approaches to stream restoration resulted in no observable improvement in ecological condition.
Walsh et al. 2005	Distributed stormwater retrofits installed throughout a watershed can reduce erosive forces, reestablish flow patterns that support aquatic life, and improve water quality.
Ku et al. 1992	Controlling surface runoff can raise local groundwater tables and may increase groundwater flux to the stream, potentially exacerbating nutrient loading in certain watersheds.
Additional Studies Identified as Part of This Review	
Study	**Key Findings**
Barr Engineering 2006	A paired watershed analysis and monitored runoff rates and volumes at watershed outfalls determined that rain garden implementation in a residential neighborhood reduced runoff volume by 89-92%.
Claussen 2007	A paired watershed analysis found a 97% reduction in stormwater runoff from a neighborhood treated with BMPs, including bioretention and permeable pavement, during the construction period, which remained lower than expected (74%) during the post-construction period.
Loperfido et al. 2014	Catchment-wide application of distributed BMPs improved stream hydrology compared to centralized BMPs, but not enough to fully replicate forested catchment stream hydrology based on an analysis of hydrologic data in four Chesapeake Bay catchments.
Covington 2015	Observations and modeling results suggest that Carroll County's sand filter designs produce a hydrologic response that exceeds Maryland's "forest in good condition" performance standard that reduces or ceases bank retreat and revegetation of riparian areas downstream of the BMP.
Lyerly et al. 2014	The full recovery of a stream due to BMP implementation is a complex process, that despite expected water quality improvement at the site-scale, the long-term and full restoration of stream health may be hampered by lag effects.
Walsh et al. 2016	Five principles are presented for stormwater management necessary for protecting stream ecosystems: 1) the ecosystems to be protected and a target ecological state should be explicitly identified; 2) the post-development balance of evapotranspiration, stream flow, and infiltration should mimic the predevelopment balance, which typically requires keeping significant runoff volume from reaching the stream; 3) stormwater control measures (SCMs) should deliver flow regimes that mimic the predevelopment regime in quality and quantity; 4) SCMs should have capacity to store rain events for all storms that would not have produced widespread surface runoff in a predevelopment state, thereby avoiding increased frequency of disturbance to biota; and 5) SCMs should be applied to all impervious surfaces in the catchment of the target stream.
Walsh et al. 2012	In catchments with as little as 5-10% total imperviousness and poor in-stream ecological condition, conventional stormwater drainage resulted in reduced baseflows and increased frequency and magnitude of storm flows. In similarly impervious catchments, but with good ecological condition, drainage was directed to forested hillslopes instead of directly piped discharge to the stream. This indirect drainage did not result in the hydrologic changes associated with conventional stormwater drainage. In urbanized catchments, dispersed urban stormwater

	retention measures can potentially protect urban stream ecosystems by mimicking the hydrologic effects of informal drainage, if sufficient water is harvested and kept out of the stream, and if discharged water is treated to a suitable quality.
Aulenbach et al. 2017	Trends among eight small watersheds in Gwinnett County, GA were compared, using a time trend study design from 2001-2008. Trend relations indicated that for every 1% increase in watershed effective impervious area (EIA), the required increase in EIA treated by BMPs to counteract the effects of increased peak streamflow, stormwater yield, and storm streamflow runoff ranged from 1.1% to 2.6%.
Meierdiercks 2015	The results of preliminary stormwater modeling analyses in the Kromma Kill New Hall subwatershed suggest that green infrastructure applied at the watershed-scale does effectively reduce flooding peaks and volume. In this model, a 100- year storm is applied to the hypothetical watershed using 5 different design scenarios: 17% of the total area of the watershed retrofitted with a mix of GI (bioretention cells, infiltration trenches, porous pavement, and rain barrels), 17% of the area retrofitted with just bioretention cells, 17% with just infiltration trenches, 17% with just porous pavement, and 17% with just rain barrels. Results suggest that all GI scenarios result in decreased peak discharge and runoff ratios, with the infiltration trenches, porous pavement, and rain barrels most effectively decreasing peak discharge and runoff ratios.
Pennino et al 2016	Watersheds in Baltimore Co and Montgomery Co, MD with more than 10% of their total area treated by green infrastructure were found to have less flashy hydrology, with 44% lower peak runoff, 26% less frequent runoff events, and 26% less variable runoff, when controlling for watershed size and percent impervious surface cover. Based on multi-linear regression, with % green infrastructure as a continuous variable and impervious surface and watershed size as covariates, all of the hydrology metrics (peak runoff, peak frequency, hydrograph duration, CV of runoff, and volume to peak ratio) showed a significant relationship with % SGI (p b 0.05), except baseflow. Peak runoff was found to be significantly correlated with detention ponds and shallow marshes; peak frequency with sand filters, infiltration trenches, and bioretention; volume to peak frequency with sand filters and infiltration trenches; hydrograph duration with shallow marshes, sand filters, and infiltration trenches; CV of runoff with all but detention ponds and wet ponds. Overall, sand filters and infiltration trenches appear to have the greatest relationships with the hydrologic metrics, possibly due to prevalence of these types and their ability to increase infiltration.
Fleischmann 2016	LID, modeled as a reduction in % impervious cover (IC), can greatly reduce stormwater runoff. A study of 12 stream sites in Hartfort, CT found that a 5% IC reduction decreased runoff by up to 16% for the 1-yr event. For a 30 %IC reduction, the runoff decreases by 68 to 88%. However, LID implementation in highly urbanized watersheds is complex. Runoff is not reduced or eliminated at many sites even for a 30% IC reduction under a 1-yr storm event. For this watershed, assessment indicates that factors in addition to contributing area and %IC have a hydrologic impact. The two stream sites located at confluences have the greatest total and peak flow indicating that stream length may factor into runoff reduction assessment. Our assessment suggests that while IC reduction can be an integral component of a stormwater mitigation plan, the application may be limited in an urbanized setting.
Roy et al. 2008	Whether localized mitigation of stormwater runoff will result in downstream improvements will depend on the amount of untreated stormwater runoff remaining in the watershed. Sustainable urban stormwater management is attainable with existing technology; however, streams remain impaired because low impact development (LID) projects are presently implemented as small-scale demonstrations scattered amid a matrix of conventional stormwater drainage. There is a need for proof-of-concept that LID technologies distributed throughout watersheds (in both new development and retrofit contexts) will be sustainable and improve downstream ecosystem quality. As of the publication date of this article, there were no examples of watershed-scale retrofit of stormwater infrastructure, replacing conventional stormwater drainage with LID tools.
Emerson 2003	This modeling study of a watershed with more than 100 detention basins in SE Pennsylvania showed that the detention basins have essentially no attenuating effect on peak stream flow. It was shown that the detention basins have been designed for only 3% of the yearly precipitation volume and therefore have little effect on the watershed wide flow regime, and in some cases, little effect on the basin's local stormwater flow. The results also show that the benefits of a volume-based approach would far exceed those realized from a release-rate, detention-basin-based approach. Modeling infiltration of only the first 0.5 inch of each daily precipitation depth can theoretically account for a 1.5 cfs increase in base flow, which represents an 8% increase for the watershed.

Bledsoe 2002	Hydrologic and sediment transport modeling were used for a small watershed in Colorado to examine the effectiveness of typical stormwater management policies in reducing the potential for stream-channel erosion. In order to reduce the post-development erosion potential to a level approximating the pre-development condition, a detention storage volume 61% greater than a peak control detention facility was needed. Design of stormwater facilities based on time-integrated sediment-transport capacity may inadvertently result in channel instability and substrate changes unless the approach accounts for the frequency distribution of sub-bank-full flows, the capacity to transport heterogeneous bed and bank materials, and potential shifts in inflowing sediment loads.
Jefferson et al. 2017	One hundred empirical and modelling studies of stormwater management effectiveness at the watershed scale in diverse physiographic settings were reviewed. Effects of networks with SCMs that promote infiltration and harvest have been more intensively studied than have detention-based SCM networks. Studies of peak flows and flow volumes are common, whereas baseflow, groundwater recharge, and evapotranspiration have received comparatively little attention. Even where impervious area is treated with SCMs, watershed function may not be restored to its predevelopment condition because of the lack of treatment of all stormwater generated from impervious surfaces; non-additive effects of individual SCMs; and persistence of urban effects beyond impervious surfaces. Given designs of individual SCMs, an SCM network aiming to achieve predevelopment hydrologic function may have to include redundant SCMs to ensure no run-off is generated. Micro-scale source control SCMs (e.g., permeable pavement sidewalks and driveways, downspouts with dry wells, and streetside swales) that treat run-off directly where it is generated could be effective at treating the full volume of stormwater generated across a wide range of hydrologic conditions.
Hawley et al. 2013	By compiling available cost data of infrastructure damages attributable to channel instability in a Northern Kentucky case study, this paper underscores the business case for a recalibration of stormwater management for stream channel stability and infrastructure sustainability. To convert a post-developed flow regime to the pre-developed disturbance regime in the receiving channel of a 0.3mi^2 watershed with 26% impervious cover was estimated to cost \$2-\$10 million per mi^2. In comparison, stream restoration in an adjacent watershed with similar conditions was estimated at \$30 million per mi^2.
Fanelli et al. 2017	Eleven headwater streams that spanned an urbanization–restoration gradient (4 forested, 4 urban‐degraded, and 3 urban‐degraded) were evaluated for changes in watershed hydrologic function from both urbanization and watershed restoration due to RSC implementation. Discrete discharge and continuous, high‐frequency rainfall‐stage monitoring were conducted in each watershed. These datasets were used to develop 6 hydrologic metrics describing changes in watershed storage, flowpath connectivity, or the resultant stream flow regime. The hydrological effects of urbanization were clearly observed in all metrics, but only 1 of the 3 restored watersheds exhibited partially restored hydrologic function. At this site, a larger minimum runoff threshold was observed relative to the urban‐degraded watersheds, suggesting enhanced infiltration of stormwater runoff within the restoration structure. However, baseflow in the stream draining this watershed remained low compared to the forested reference streams, suggesting that enhanced infiltration of stormwater runoff did not recharge subsurface storage zones contributing to stream baseflow.

Whether localized mitigation of stormwater runoff will result in downstream improvements will depend on the amount of untreated stormwater runoff remaining in the watershed (Roy et al. 2008). Further, alterations to the downstream channel and other factors such as legacy sediments (Walter and Merritts 2008) which affect the geomorphology of the stream channel and floodplain can complicate the expected outcomes of watershed restoration. Most studies that evaluate the effect of BMPs on streams are limited to measurements of the effect of runoff volume reduction from individual BMPs, with monitoring of outfalls. In one such study, Barr Engineering (2006) conducted a paired watershed analysis and monitored runoff rates and volumes at the watershed outfalls to determine that rain garden implementation in a residential neighborhood reduced runoff volume by 89-92%. Similarly, Claussen (2007) conducted a paired watershed analysis and found a 97% reduction in stormwater runoff from a neighborhood treated with BMPs, including bioretention and permeable pavement, during the construction period, which remained lower than expected (74%) during the post-construction period.

There are few examples of widespread BMP implementation at a watershed scale with the explicit objective of protecting or restoring a receiving stream (Roy et al., 2008). However, recent findings suggest unstable stream banks in headwater streams can recover channel stability due to the implementation of BMPs that treat nearly 100% of the drainage area (Covington 2015). For example, observations and modeling results suggest that Carroll County's sand filter designs produce a hydrologic response that exceeds Maryland's "forest in good condition" performance standard (MDE 2010) that reduces or ceases bank retreat and revegetation of riparian areas downstream of the BMP. Additional information about Carroll County's sand filter designs is available at http://ccgovernment.carr.org/ccg/resmgmt/doc/Forms/swm.supplement.pdf?x=1464697527476.

Once the frequency of untreated runoff has been limited to near predevelopment levels, Walsh et al. (2016) recommend that BMPs be designed to deliver the volume and temporal pattern of flows that mimic what would formerly have been delivered as base flow from the land now covered by impervious surfaces. This can be achieved by promoting infiltration of a similar amount of water as would have been infiltrated in the predevelopment state. In a modeling study of a southeast Pennsylvania watershed, Emerson (2003) found that 82 detention basins treating 39% of the directly connected impervious cover and modified to infiltrate the first 0.5 inch of rainfall would achieve an 8% increase in stream baseflow. Alternatively, engineered systems can be used that mimic natural baseflow regimes by means of controlled discharge, such as lined bioretention systems suggested by DeBusk et al. (2011) that have the potential to achieve near-channel baseflow regimes.

Walsh et al. (2016) also recommend that BMPs be designed and placed such that runoff from all impervious area of the catchment is managed. BMPs are often opportunistically distributed throughout a jurisdiction to minimize cost and ensure geographic equity among landowners and communities. Roy et al. (2008) suggest that sustainable urban stormwater management is attainable with existing technology; however, streams remain impaired because projects are presently implemented as small-scale demonstrations scattered amid a matrix of conventional stormwater drainage. This results in the treatment of runoff from only a portion of impervious surfaces. In catchments with as little as 5-10% total imperviousness, Walsh et al. (2012) found that conventional stormwater drainage reduces contributions to baseflows and increases the frequency and magnitude of storm flows. But in similar impervious catchments with informal drainage to forested hillslopes and without a direct piped discharge to the stream, there was little such hydrologic change. They suggest that urbanized catchments with dispersed urban stormwater retention measures can potentially protect urban stream ecosystems by mimicking the hydrologic effects of informal drainage, if sufficient water is harvested and kept out of the stream, and if discharged water is treated to a suitable quality. Similarly, Loperfido et al. (2014) evaluated hydrologic data in four Chesapeake Bay catchments and found that catchment-wide application of distributed BMPs improved stream hydrology compared to centralized BMPs, but not enough to fully replicate forested catchment stream hydrology.

In spite of this research, there are practical limitations to the ability of watershed-scale BMP implementation to maintain healthy streams. These limitations suggested by Roy et al. (2008) include: 1) limited space for storing and infiltrating stormwater, 2) contaminants may overwhelm these technologies, and/or 3) surpassing the recovery thresholds of the system. Fanelli et al (2017) found that enhanced infiltration in stormwater runoff from a restored watershed due to RSC implementation resulted in lower baseflow compared to forested reference streams, suggesting that enhanced infiltration of stormwater runoff did not recharge subsurface storage zones contributing to stream baseflow. Lammers (2015) also noted that the reduction in sediment supply could subsequently cause instability and erosion in downstream reaches that become sediment starved. In these cases, sustainability may not be feasible, although this remains untested.

3.2 Channel Reconfiguration

Historically, channel reconfiguration has been the subject of a great deal of controversy among researchers and practitioners, primarily regarding the use of template-based restoration approaches over more process-based approaches (Doyle et al. 1999; Simon et al. 2007; Lave 2009). The primary argument centers on the use of the industry standard for stream restoration design, the Natural Channel Design (NCD) method (Rosgen 1994), which many argue is a "template-based" approach. The NCD method uses a Channel Evolution Model similar to Schumm et al. (1984) to predict channel trajectory for determining appropriate stable reference reaches to provide channel dimension, pattern and profile for design. Stream designers today are using more sophisticated approaches combining the NCD approach with sediment transport models and two-dimensional hydraulic modeling.

Channel Reconfiguration was included in the Lammers (2015) literature review and defined as, "One of the more intensive and expensive stream restoration strategies, channel reconfiguration may entail reconnection of a historically abandoned channel, partial channel realignment, or complete construction of a new channel." The goal is typically to decrease velocities by reducing slope and increasing sinuosity and is typically accompanied by other stream restoration strategies such as erosion protection and installation of in-stream structures. Reducing in-stream velocities may increase hydraulic residence time and nutrient uptake. Channel reconfiguration can also help balance sediment transport to avoid channel downcutting or loss of flood capacity (Lammers 2015).

Since channel reconstruction is typically used in conjunction with other restoration strategies, it is difficult to isolate individual effects. The high cost of channel reconstruction projects (Bernhardt and Palmer 2007; Bernhardt et al. 2005) may make their use as a nutrient reduction strategy undesirable. However, these projects are often constructed to meet other restoration objectives and may also provide fortuitous nutrient retention benefits.

Table 3-2 provides a summary of the channel reconfiguration studies included in the Lammers (2015) literature review, as well as additional studies identified as part of this review.

Table 3-2. Summary of Channel Reconfiguration Studies Included in the Lammers (2015) Literature Review and New Studies Identified as Part of this Review.

Channel Reconfiguration Studies Included in Lammers (2015) Literature Review	
Study	**Key Findings**
Bukaveckas 2007	Channel re-meandering subsequently decreases slope and velocity, increasing hydraulic retention time and nutrient uptake rates.
Claushulte 2015	Channel reconstruction and grade control resulted in successful nutrient retention in a previously incised stream, although a lack of pre-restoration monitoring makes a full evaluation difficult.
Stewart 2008	A complete channel reconstruction (including floodplain reconnection and bank stabilization) led to 33-42% reductions in nitrogen loads and 43-60% reductions in phosphorus loads.
Sudduth et al. 2011	Slightly higher nitrate uptake rates were observed in streams restored by reconstructing the channel to a "natural and stable" planform. However, these higher uptake rates were likely the result of higher primary productivity from increased water temperature and light availability due to removal of riparian vegetation during construction.
Hines and Hershey 2011	Higher in-stream temperatures, greater algal biomass, and increased ammonium processing in restored reaches due to lower canopy cover, leading to the suggestion that riparian zones be managed to allow for both shaded and unshaded portions to improve nutrient retention.
Kasahara and Hill 2007	Re-creation of channel meanders and point bars may stimulate lateral hyporheic exchange, presumably increasing nutrient processing.
Zarnetske et al. 2011	Significant denitrification and net nitrogen removal have been observed in the hyporheic zones of natural gravel bars, suggesting that nutrient processing in constructed gravel bars may also be important.
Doyle et al. 2003	Although increasing hydraulic retention time is important, restoring conditions that enhance uptake processes (e.g. habitat heterogeneity) will likely be more effective at increasing nutrient retention rather than simply decreasing velocity and depth.

Additional Studies Identified as Part of This Review	
Study	**Key Findings**
Mason et al. 2012	This study documents changes in hydrologic transport and variation in channel water velocity prior to and immediately following large-scale channel realignment along Silver Bow Creek in southwestern Montana. Channel restoration increased water residence time in the channel by increasing sinuosity, decreasing channel slope, and increasing pool frequency. However, channel realignment yielded a reduction in the fine-scale variation in streambed topography. Water velocity profiles in post-realignment channels, thus, exhibited greater uniformity at short spatial scales. As a result, and possibly due to loss of hyporheic exchange, transient storage within the system declined after channel realignment, offsetting some of the increase in residence time associated with slower advective velocities.
Miller and Kochel 2009	Site assessment and monitoring data were analyzed for 26 stream restoration projects in North Carolina where the channel was reconfigured. Post-project changes in channel capacity were highly variable from site to site, but more than 60% of the projects underwent, on average at a given site, at least a 20% change in channel capacity. It is also argued that where space permits an enhanced natural channel, adjustment approach is likely to be more effective than projects based on natural channel design.
Clark and Montemarano 2017	Results from short-term assessment (i.e., one and three years' post restoration) of habitat variables (e.g., reach depth, substrate, and canopy cover) and fish community composition and structure (using electrofishing surveys; e.g., proportion of juveniles and tolerant fishes) from a 675 m section of Eagle Creek (Portage County, OH, USA) restored using channel remeandering in August 2013. Overall, in the short-term (<=3 years), new channel colonizing communities were unable to recover to reflect upstream community composition and structure, and fish communities downstream of restoration were negatively impacted. Restoration techniques created a relatively homogenous habitat in the new channel that was shallow, dominated by fine sediments, and completely lacked canopy cover.
Tullos et al. 2009	This study compared physical habitat variables, taxonomic and functional-trait diversities, taxonomic composition, and functional-trait abundances between 24 pairs of upstream (control) and downstream reconfigured (restored) reaches in 3 catchment land uses (urban, agricultural, rural) across the North Carolina Piedmont. Restoration affected aquatic assemblages only in agricultural and rural catchments. Channel reconfiguration was found to disturb food and habitat resources in stream ecosystems.
Doheny et al. 2012	Data collected from 2002 through 2008 by the U.S. Geological Survey, in cooperation with the U.S. Environmental Protection Agency, were used to assess geomorphic characteristics and geomorphic changes over time in a reach of Minebank Run, a small urban watershed near Towson, Maryland, prior to and after its physical restoration in 2004 and 2005. Post-restoration, lateral erosion has been reduced with fewer indications of channel widening. Flood flows can now inundate sections of the overbank area, and also bypass the main channel in small sections of the study reach, which was not possible before restoration. Much of the post-restoration geomorphic variability is due to alternating patterns of sediment storage and removal, and shifting of the channel thalweg in contrast to channel degradation and widening, and lateral erosion from receding cut banks observed during the pre-restoration monitoring. Composite particle-size analyses of the channel bed from pebble counts over time indicated that sources of fine sediment, possibly from bank erosion, still exist in the watershed despite restoration of the stream channel.
Sivirichi et al. 2011	This study compared dissolved nitrogen and carbon dynamics in two restored stream reaches (Minebank Run and Spring Branch) utilizing channel reconfiguration and two un-restored reaches (Dead Run and Powder Mill) in Baltimore. They concluded that restored stream reaches were a net sink for total dissolved nitrogen (TDN) and a net source for dissolved organic carbon (DOC). By contrast, the un-restored urban reaches had a net release of TDN and net uptake for DOC.
Smith and Prestegard 2005	A rehabilitation project conducted in a reach of Deep Run, Maryland (United States), was monitored in order to assess commonly used approaches to channel design that rely on classification systems to describe the channel form, empirical relations to predict channel dimensions, and a single design discharge to evaluate the hydraulic conditions. Results from field measurements and observations indicated that the morphological conditions created in Deep Run were unstable. The morphology of the constructed channel was altered by storm flows smaller than the designed bank-full discharge and by floods that extended the flow width to the limits of the created meander belt.

The nutrient reduction capabilities of channel reconfiguration are varied, as shown in the Lammers (2015) literature review. Additional research conducted for this review yielded similar results. Sivirich et al. (2011) found that restored stream reaches in Baltimore were a net sink for total dissolved nitrogen (TDN) and a net source for dissolved organic carbon (DOC). By contrast, the unrestored urban reaches had a net release of TDN and a net uptake for DOC.

The effectiveness of channel reconfiguration on geomorphic stability also varies among the literature reviewed. For example, Doheney et al. (2012) monitored a channel reconfiguration project at Minebank Run, an urban catchment in Maryland over a six-year period. They demonstrated that following restoration there was reduced lateral erosion, fewer indications of channel widening and greater variability in patterns of sediment storage and removal when compared with the large volume of sediment lost in the year prior to the project. Interestingly, despite this trend toward stabilization, composite particle-size analyses of the channel bed from pebble counts over time indicated that sources of fine sediment, possibly from bank erosion, still exist in the watershed even with restoration of the stream channel. In comparison, instream structures commonly used in channel reconfiguration along highly dynamic rivers are often incapable of stabilizing the channel even temporarily as intended and their benefits in terms of creating aquatic habitat along reconfigured channels are generally less than initially expected. Miller and Kochel (2009) conducted site assessment and monitoring data analysis for 26 stream restoration projects in North Carolina where the channel was reconfigured and found that more than 60% of the projects underwent at least a 20% change in channel capacity. They suggest that the potential for creating a reconfigured channel in an equilibrium state is low, whereas the potential costs of post-project maintenance and/or redesign and implementation are high. Similarly, Smith and Prestegard (2005) found that morphological conditions created for a channel reconfiguration project in Maryland were unstable and that the morphology of the constructed channel was altered by storm flows smaller than the designed bankfull discharge and by floods that extended the flow width to the limits of a created meander belt.

Hydrologic residence time in streams is rarely considered as a response variable for assessing restoration design strategies. However, residence time is an important control on ecosystem processes such as the biotic uptake and processing of excess nutrients and other pollutants in streams. Mason et al. (2012) found that channel realignment yielded a reduction in the fine-scale variation in streambed topography, which resulted in a decline in transient storage within the system after channel realignment, offsetting some of the increase in residence time associated with slower advective velocities

Channel reconfiguration can have negative short-term impacts, such as the loss of in-stream and riparian habitats and increased erosion. Clark and Montemarano (2017) found that colonizing fish communities in a newly reconfigured channel were unable to recover to reflect upstream community composition and structure and restoration activity negatively impacted fish communities in sites downstream of restoration over time. Restoration techniques created a relatively homogenous habitat in the new channel that was shallow, dominated by fine sediments, and completely lacked canopy cover. Similarly, Tullos et al. (2009) found that channel reconfiguration disturbed food and habitat resources in agricultural and rural catchments across 24 reconfigured reaches in North Carolina. Restoration affected benthic macroinvertebrate assemblages in agricultural and rural catchments. The response to restoration in urban catchments was hypothesized to be minimal due to the biota already being filtered by the effects of urbanization.

CHAPTER 4

Summary of State and Municipal Survey Results Within and Outside of the Chesapeake Bay Watershed

The Center for Watershed Protection developed surveys using Survey Monkey (Appendices A and B) that were distributed to states and municipalities within and outside of the Chesapeake Bay watershed regarding their use or possible interest in crediting guidance for stream restoration projects developed by WRF in 2016. There are multiple components, processes, and administrative requirements for a successful crediting program that involves stream restoration. The purpose of these surveys was to highlight experiences that utilities and municipalities have had with stream restoration protocols across the Chesapeake Bay watershed, as well as states outside of the Chesapeake Bay watershed that have adopted or are considering adopting stream crediting/trading programs that could benefit from the WRF Stream Restoration Crediting Guidance. The surveys were conducted between March 6 and April 6, 2018.

4.1 Survey of States and Municipalities Inside the Chesapeake Bay Watershed

This survey was conducted of states and municipalities within the Chesapeake Bay watershed to identify incentives/impediments to using the WRF Stream Restoration Crediting Guidance which includes protocols 1-3 of the existing crediting framework for the Chesapeake Bay Program. In addition, states and municipalities were asked whether they are aware of the stream restoration database (USR14) and whether they are willing to utilize this tool. The survey questions are provided in Attachment A and a spreadsheet of the survey responses is included in Appendix C.

The survey was distributed to states and municipalities within the Chesapeake Bay watershed through:

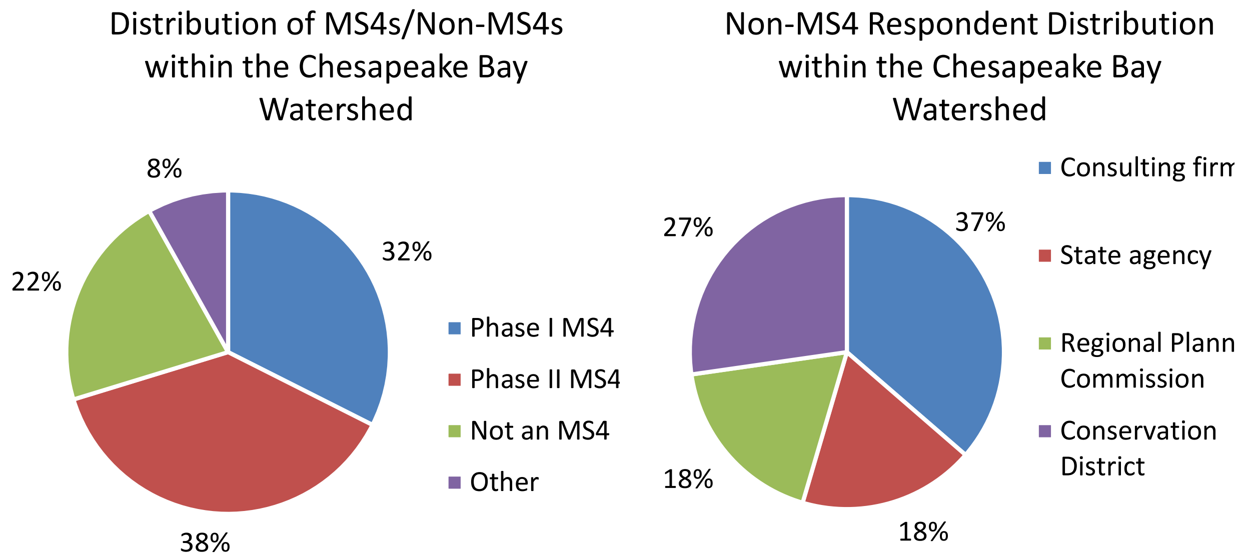
- List of 78 MS4 permittee contacts within Virginia compiled by the Center.
- List of 32 municipal contacts within Pennsylvania that attended a recent Stream Restoration workshop conducted by the Center in December 2017.
- Maryland Department of the Environment distribution of the survey to MS4s within Maryland.
- List of 1,930 state and local government contacts across the country maintained by the Center, which includes contacts within the Chesapeake Bay watershed.

A total of 75 initial survey responses were filtered as follows and resulted in a final response count of 37:

- Ten duplicate entries were removed. These appear to be respondents that initially started the survey and returned at a later time to complete the survey through a new entry.
- Two survey test responses were removed.
- Twenty-six responses were removed because they did not respond to the survey questions.

4.1.1 Respondents

Of the 37 responses to the survey of states and municipalities within the Chesapeake Bay watershed, the majority (26 out of the 37) were either Phase I or Phase II MS4s. The 11 respondents that were not MS4s consisted of consulting firms, state agencies, regional planning commissions, and conservation districts.

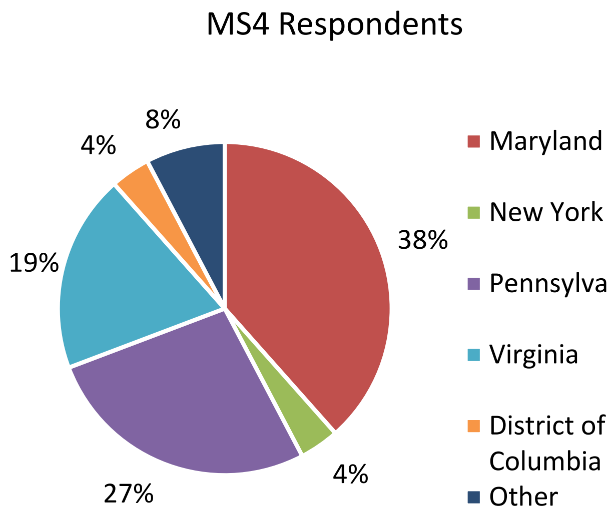


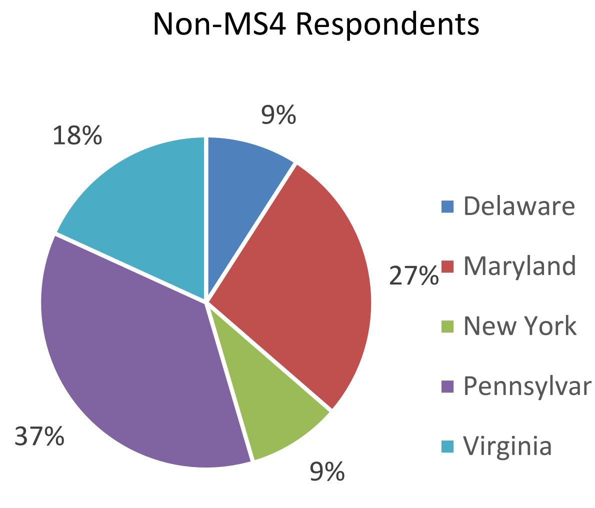
Organization Type	Number of Respondents
Phase I MS4	12
Phase II MS4	14
Not an MS4	8
Other	3

Non-MS4 Type	Number of Respondents
Consulting firm	4
State agency	2
Regional Planning Commission	2
Conservation District	3

Figure 4-1. Distribution of Survey Respondents Within the Chesapeake Bay by Organization Type.

The majority of MS4 respondents were from Maryland (38%), followed by Pennsylvania (27%), and Virginia (19%). Most non-MS4 respondents were from Pennsylvania (37%), followed by Maryland (27%), and Virginia (18%).





State	Number of Respondents
Maryland	10
New York	1
Pennsylvania	7
Virginia	5
District of Columbia	1
Other	2

State	Number of Respondents
Delaware	1
Maryland	3
New York	1
Pennsylvania	4
Virginia	2

Figure 4-2. Distribution of Respondents from Each State Within the Chesapeake Bay Watershed.

4.1.2 Number and Types of Stream Restoration Projects

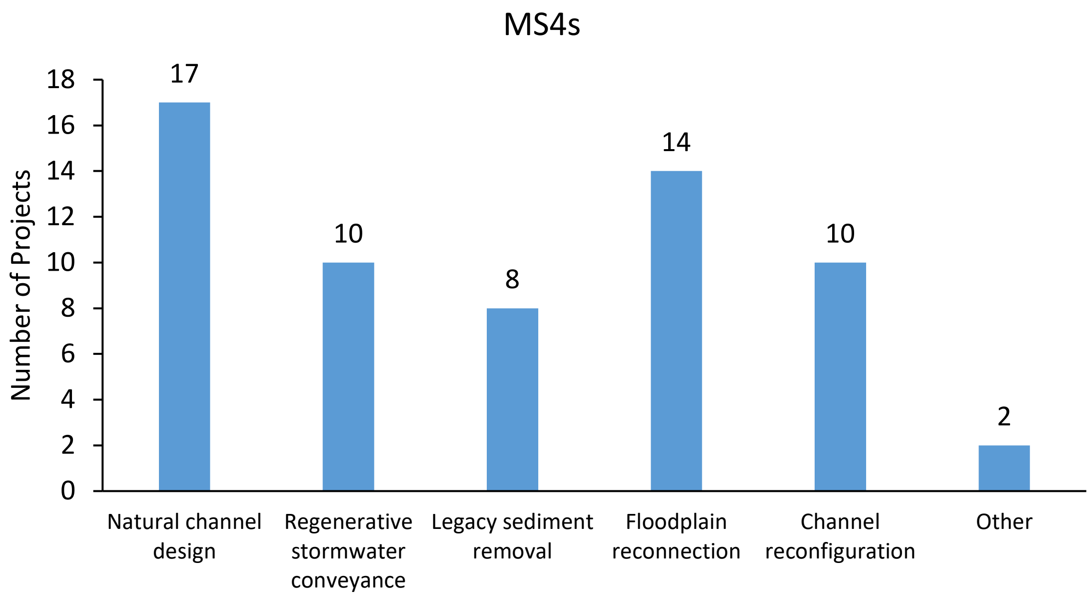
Within the Chesapeake Bay watershed, the majority of MS4s and non-MS4s have completed ten or fewer stream projects in the past four years since implementation of the Chesapeake Bay Program stream restoration protocols. For those respondents that that have installed stream restoration projects, the average number of projects completed by MS4s was 12.8, while non-MS4s averaged 18.6 projects. Nine MS4 and Two non-MS4 respondents indicated they have not done any stream restoration projects. The largest number of projects reported by MS4s was by Prince George's County Department of Environmental Protection in MD (61 projects), followed by Chemung County Soil and Water Conservation District in NY (50 projects), and Howard County Department of Public Works, Bureau of Environmental Services, Stormwater Management Division (33 projects). The largest number of projects reported by non-MS4s was by the Upper Susquehanna Coalition in NY (75 projects), followed by Bradford County Conservation District in PA (50 projects).

Of the MS4s, all respondents reported that the total length of stream restoration projects over the past four years was less than 20,000 linear feet. The majority of MS4 respondents reported lengths from 10,001-20,000 linear feet. The non-MS4 responses were considerably more variable; however, most respondents also indicated stream project lengths of 10,001-20,000 linear feet. The average total length of stream projects within the past four years for MS4 respondents was 7,564 linear feet, while the average for non-MS4s was 26,553 linear feet. This question may have been misinterpreted by some respondents as the average project length instead of the total length of stream restoration projects. For example, Prince George's County in MD reported that they implemented 61 stream restoration projects over the four-year timeframe and a total stream length of 17,730 linear feet, which averages to 291 linear feet per project. In comparison, Bradford County Conservation District in PA reported that they implemented 50 stream restoration projects and a total stream length of 20 miles, which averages to 2,112 linear feet per project.

All of the MS4 respondents indicated fewer than 40 planned stream projects through 2025. The majority (10 respondents) indicated they had from 1-10 planned projects, while five indicated they had no planned stream restoration projects. The Maryland Department of Transportation State Highway Administration reported the highest number of planned projects (40 projects), but indicated that this includes outfall stabilization projects, which currently are not credited with the CBP stream crediting protocols. Anne Arundel County, MD reported the second highest number of planned projects (38 projects). The majority of non-MS4 responses were fewer than 30 projects; however, two non-MS4 respondents indicated greater than 70 stream projects planned through 2025. Bradford County Conservation District in PA has 100 planned stream restoration projects, totaling 40 linear miles. The Upper Susquehanna Coalition in NY has more than 75 planned stream restoration projects, totaling 10,000 linear feet. As mentioned above, there appears to be discrepancy in the total stream restoration project length among respondents.

All of the MS4s and non-MS4s who responded they do stream restoration projects implement natural channel design projects. The second most common type of stream restoration is floodplain reconnection for MS4s and both floodplain reconnection and channel reconfiguration for non-MS4s. Regenerative stormwater conveyance was also common among the non-MS4s, which involves the use of step pools or instream weirs to spread stormflows across the floodplain. Legacy sediment removal was the least common type of stream restoration design implemented. It is important to note that floodplain reconnection is associated with NCD, legacy sediment removal and RSC projects. Channel reconfiguration can also be associated with NCD and RSC. Two MS4s who responded with "other" indicated outfall stabilization and streambank restoration, while the non-MS4 respondent who responded with "other" indicated bank stabilization.

Of the 10 MS4 and eight non-MS4 respondents who typically do channel reconfiguration projects, all indicated that it is done in combination with other project types like natural channel design or floodplain reconnection. Two MS4s and two non-MS4s that do not typically do channel reconfiguration projects indicated that when reconfiguration is done it is part of other project types. Half of the MS4 respondents that reconfigure the channel as part of other project types (six respondents) indicated that they typically reconfigure the channel to a low degree (less than 25% of the total project length reconfigured). One third of the MS4 respondents typically reconfigure the channel to a medium degree (25-50% of the total project length reconfigured) and only two respondents (17%) reconfigure the channel to a high degree (>50% of the total project length reconfigured). In comparison, an equal number of non-MS4 respondents indicated that they typically reconfigure the channel to a low, medium, and high degree.



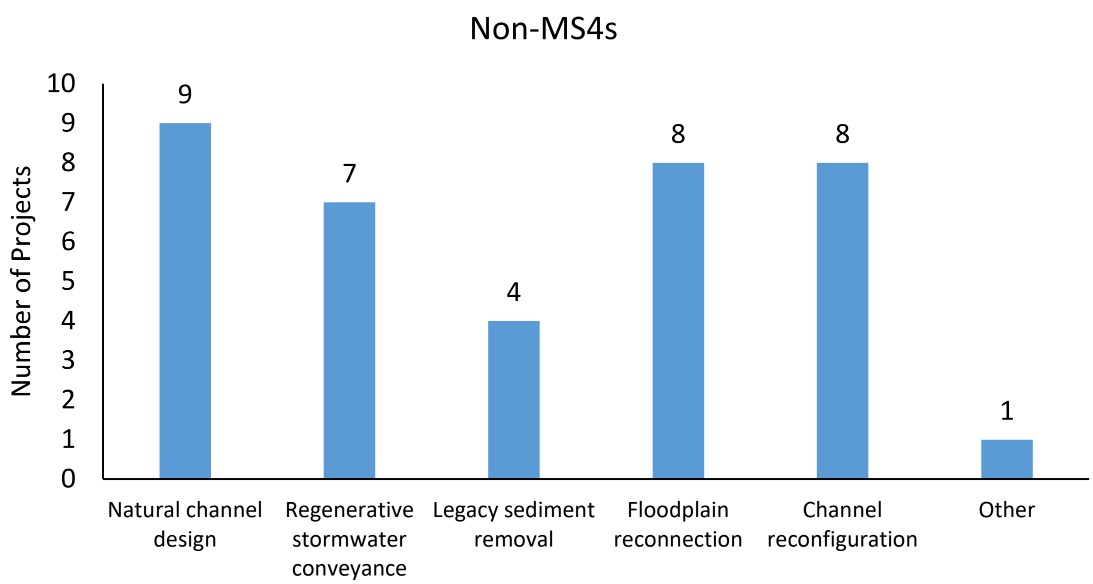
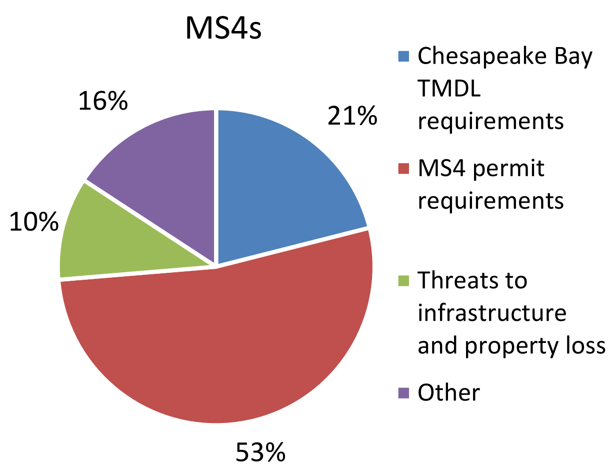


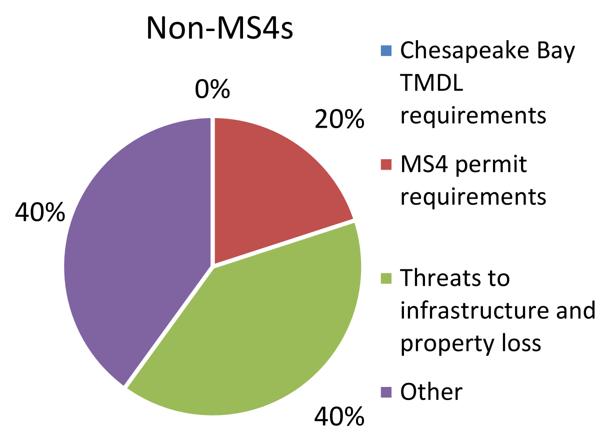
Figure 4-3. Types of Stream Restoration Projects Typically Implemented Within the Chesapeake Bay Watershed.

4.1.3 Identification of Projects and Reasons for Implementation

A variety of methods were provided for identifying stream restoration projects. Nine out of 19 MS4s that responded use potential stream restoration sites included in watershed plans and assessments, typically followed up with field investigations and feasibility analysis, such as the ability to obtain landowner permission. Four of the MS4s use visual inspections to identify streams in need of restoration based on degraded conditions such as channel instability and outfall failure. Similarly, three reported that they focus on areas with known issues, such as flood damage. One MS4 reported identification of stream restoration sites based on the ability to obtain the most sediment reduction for the least cost to meet MS4 permit requirements. The non-MS4s identify their sites through client/locality preferences, priority funding areas and watershed implementation plan (WIP) goals, funding opportunities, and interest from landowners. One also reported a focus on legacy sediment impaired sites, and another reported that the Pennsylvania Watershed Resources Registry currently under development would be a source of potential project sites.

The majority of MS4s (54%) reported MS4 permit requirements as the primary reason for implementing stream restoration projects, followed by Chesapeake Bay TMDL requirements (21%). Three MS4 respondents who responded “other” indicated stream condition improvement, habitat restoration, and a combination of reasons as their primary reason. In comparison, the majority of non-MS4s (40%) reported infrastructure and property loss as the primary reason. An additional 40% (four respondents) responded “other” and indicated legacy sediment impairment, local sediment and nutrient priorities not focused solely on Chesapeake Bay TMDL milestones, and a combination of MS4 requirements and mitigation purposes.



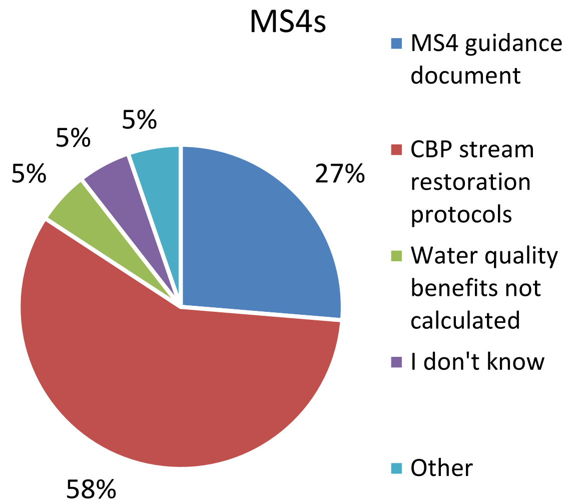


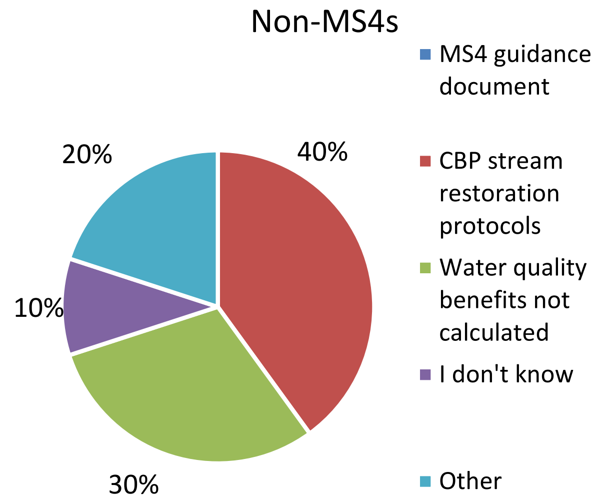
Reason for Stream Restoration Project Implementation	Number of MS4 Respondents	Number of Non-MS4 Respondents
Chesapeake Bay TMDL requirements	4	0
MS4 permit requirements	10	2
Threats to infrastructure and property loss	2	4
Other	3	4

Figure 4-4. Primary Reason for Implementing Stream Restoration Projects Within the Chesapeake Bay Watershed.

4.1.4 Crediting Stream Restoration Projects

The majority of MS4s implementing stream restoration projects (58%) use the CBP stream restoration crediting protocols to calculate water quality benefits, followed by 27% that use MS4 guidance documents. Maryland Department of the Environment, Virginia Department of Environmental Quality, and Pennsylvania Department of Environmental Protection guidance includes use of the CBP stream restoration crediting protocols. The one MS4 respondent who responded “other” indicated the Bank and Nonpoint Source Consequences of Sediment method or VA Stormwater Local Assistance Fund guidance as their method for calculating the water quality benefits. In comparison, 40% of non-MS4s use the CBP stream restoration crediting protocols. An additional 30% indicated that they do not calculate water quality benefits. Of the two non-MS4 respondents who responded “other,” one indicated a combination of CBP Stream Restoration Protocols and Wetland BMP guidance. The other indicated the use of the Bank Erosion Prediction model combined with the Bank Erosion Hazard Index (BEHI, a component of the BANCS method) at each site, followed by the use of Natural Resources Conservation Service standard nitrogen and phosphorus soil concentrations to calculate nutrient load reductions.



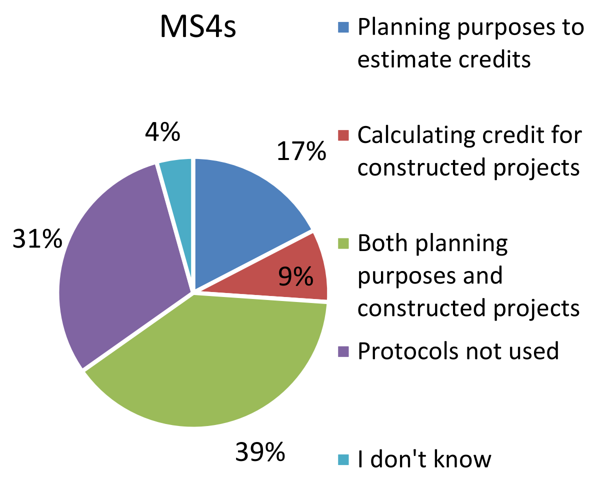


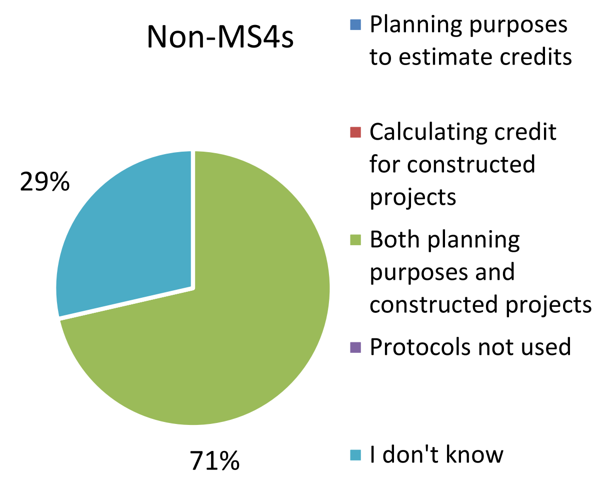
Method for Water Quality Benefit Calculation	Number of MS4 Respondents	Number of Non-MS4 Respondents
MS4 guidance document	5	0
CBP stream restoration protocols	11	4
Water quality benefits not calculated	1	3
I don't know	1	1
Other	1	2

Figure 4-5. Methods for Water Quality Benefit Calculation of Stream Restoration Projects Within the Chesapeake Bay Watershed.

Of the 26 MS4 respondents, 85% (22 respondents) indicated they were aware of the CBP Stream Restoration Expert Panel recommendations, while only half (five of 10) of the non-MS4 respondents indicated they were aware of the recommendations. In comparison, only 17% (four out of 23) of the MS4 respondents were aware of WRF’s Stream Restoration Crediting guidance. Only one out of five non-MS4 respondents indicated they were aware of the crediting guidance.

Most of the MS4 respondents (39%) that indicated they are aware of the CBP stream restoration crediting protocols are using them to calculate water quality credits for both planned and constructed projects. An additional 31% indicated they are not using the protocols and 17% are using the protocols for planning purposes only. All of the non-MS4s that indicated they are aware of the CBP stream restoration crediting protocols are using them to calculate water quality credits for both planned and constructed projects, except for two respondents that did not know.





Usage of CBP Stream Restoration Crediting Protocols	Number of MS4 Respondents	Number of Non-MS4 Respondents
Planning purposes to estimate credits	4	0
Calculating credit for constructed projects	2	0
Both planning purposes and constructed projects	9	5
Protocols not used	7	0
I don't know	1	2

Figure 4-6. Usage of CBP Stream Restoration Crediting Protocols Within the Chesapeake Bay Watershed.

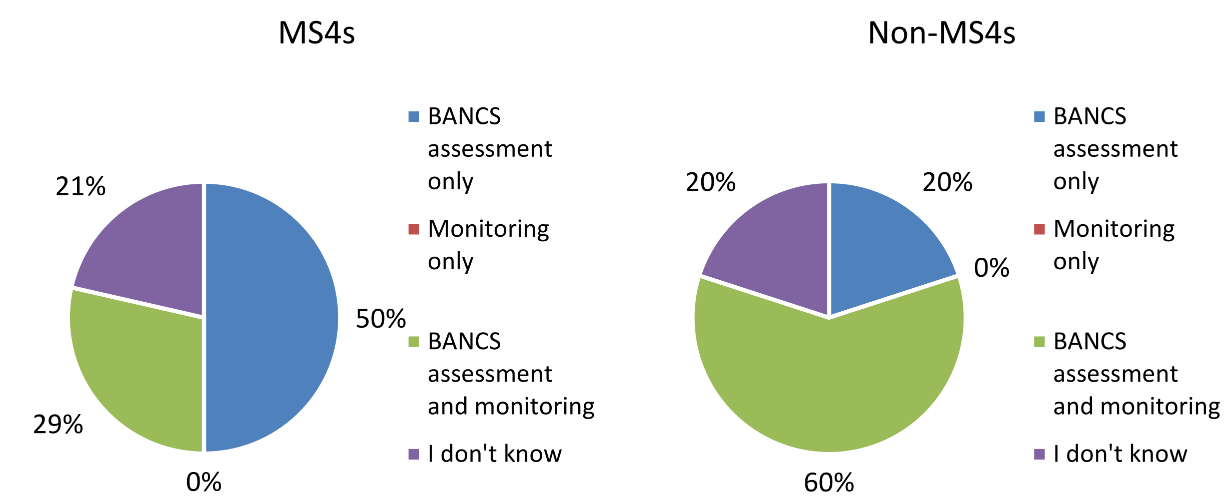
Of the seven MS4s that responded they do not use the protocols, the following reasons were provided:

- Two only use the default rate.
- One has TMDLs focused on pollutants other than nutrients and sediment.
- One noted that the protocols are predicated upon certain circumstances that don't necessarily apply to the types of streams/projects that they work with.
- One is just starting to use the protocols.
- One indicated that the protocols are too complicated, they are unable to collect the required data, and are unsure of the methodology.

Of the seven MS4 respondents who indicated they are not using the CBP stream restoration protocols, three responded they were interested in using the protocols in the future, one responded they were not interested, one did not know, and two said they were interested in learning more.

Nine MS4s and two non-MS4s provided estimates for the number of projects they’ve used the CBP stream restoration protocols for. The majority of MS4 respondents (five out of nine) have used the CBP protocols for both planned and constructed projects. The highest number of projects that have used the protocols for planning purposes was done by Anne Arundel County, MD with 38 reported projects. The two non-MS4 respondents both reported between four and five planning and constructed projects that have used the protocols.

Fourteen of the MS4s responded that they are using CBP stream crediting protocol one, with half (seven respondents) conducting BANCS assessments only. An additional 29% (four respondents) are conducting both BANCS assessments and monitoring and 21% (three respondents) did not know. Five the non-MS4s responded that they are using CBP stream crediting protocol one, with 60% (three respondents) conducting BANCS assessments and monitoring. One non-MS4 is conducting BANCS assessments only, and one respondent did not know. There were no MS4s or non-MS4s that reported they are only doing monitoring.

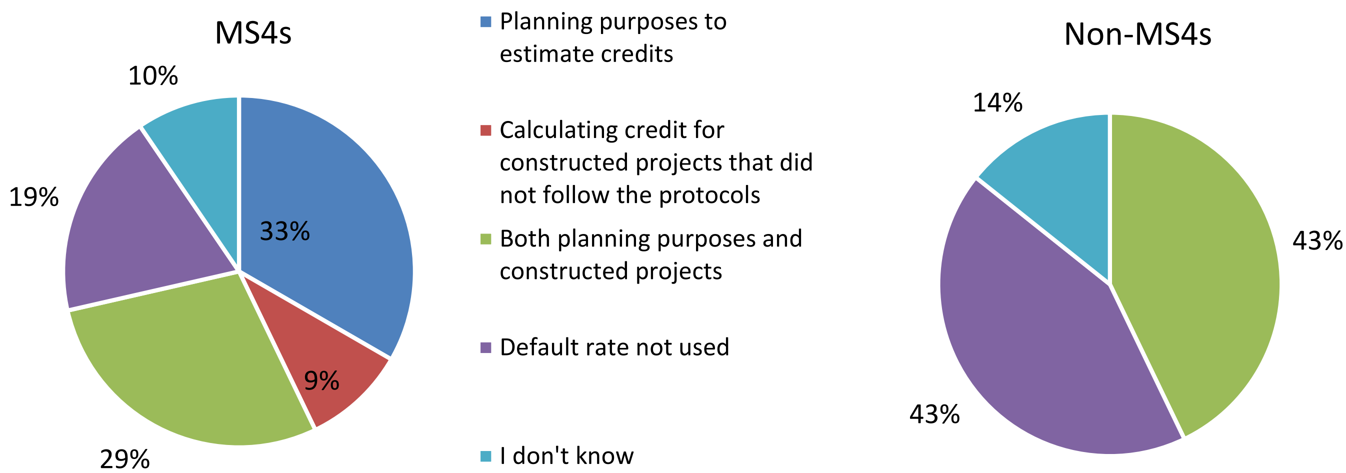


Protocol 1 BANCS/Monitoring	Number of MS4 Respondents	Number of Non-MS4 Respondents
BANCS assessment only	7	1
Monitoring only	0	0
BANCS assessment and monitoring	4	3
I don't know	3	1

Figure 4-7. Usage of BANCS Assessment and/or Monitoring for Protocol 1 Within the Chesapeake Bay Watershed.

Seven MS4s described their monitoring approach for Protocol 1. Of the seven, four indicated they use a combination of the BANCS assessment that is validated with monitoring data from cross sections and bank pins. Three of the MS4s conduct BANCS assessment only and noted that monitoring would be too cost prohibitive. Two of the MS4s reported that the monitoring varies by consultant conducting the restoration project and that they didn't have any additional details. Four non-MS4s described their monitoring approaches for Protocol 1. One conducts repeated topographic and geospatial survey pre- and post-construction, which has included lidar. One conducts BANCS assessments with surveyed cross sections over a one-year period, except when time doesn't allow, in which case they solely rely on the BANCS results based on regional curves. One non-MS4 only conducts monitoring as part of design and as-built check, including longitudinal profiles, cross sections and BANCS assessments. The final non-MS4 indicated that their environmental team does the monitoring work and they don't know the details on what is done.

The majority of the MS4s (33%) that responded use the default rate for planning purposes to estimate credits. An additional 29% use the default rate for both planning purposes and constructed projects that do not follow the protocols. The four respondents that are not using the default rate are also not using the CBP guidance. The non-MS4s that responded are split between either not using the default rate or using it for planning purposes and constructed projects that do not follow the protocols. Of the three non-MS4s that are not using the default rate, one is not using calculating water quality benefits of their stream restoration projects. The other two use the protocols for both planning purposes and constructed projects instead of the default rate.



Usage of Default Rate	Number of MS4 Respondents	Number of Non-MS4 Respondents
Planning purposes to estimate credits	7	0
Calculating credit for constructed projects that did not follow the protocols	2	0
Both planning purposes and constructed projects	6	3
Default rate not used	4	3
I don't know	2	1

Figure 4-8. Usage of the Default Rate Within the Chesapeake Bay Watershed.

Eight MS4s provided the number of projects for which they have used the default rate over the past four years since the CBP stream restoration crediting guidance was first approved. The majority (five respondents) indicated they have used the default rate for one to five planning projects. The largest number was provided by MD SHA that has used the default rate for 30 planning projects, followed by the York County Planning Commission in PA that has used the default rate for 25 planning projects. Of the same eight MS4 respondents, the majority (five respondents) said they have used the default rate for one to five constructed projects. None of the non-MS4 respondents answered this question.

In terms of CBP stream crediting protocol training, 11 MS4s indicated that they attended a conference presentation, seven attended a Center for Watershed Protection webcast, and four attended a Chesapeake Stormwater Network webcast. The three MS4 respondents who responded “other” indicated BANCS training, a CWP seminar, and training in conjunction with a grant project as alternative training types. Only three non-MS4s attended a conference presentation and only one attended a CWP webcast. The one non-MS4 respondent who responded “other” indicated that some employees had attended professional trainings regarding the implementation of natural design techniques.

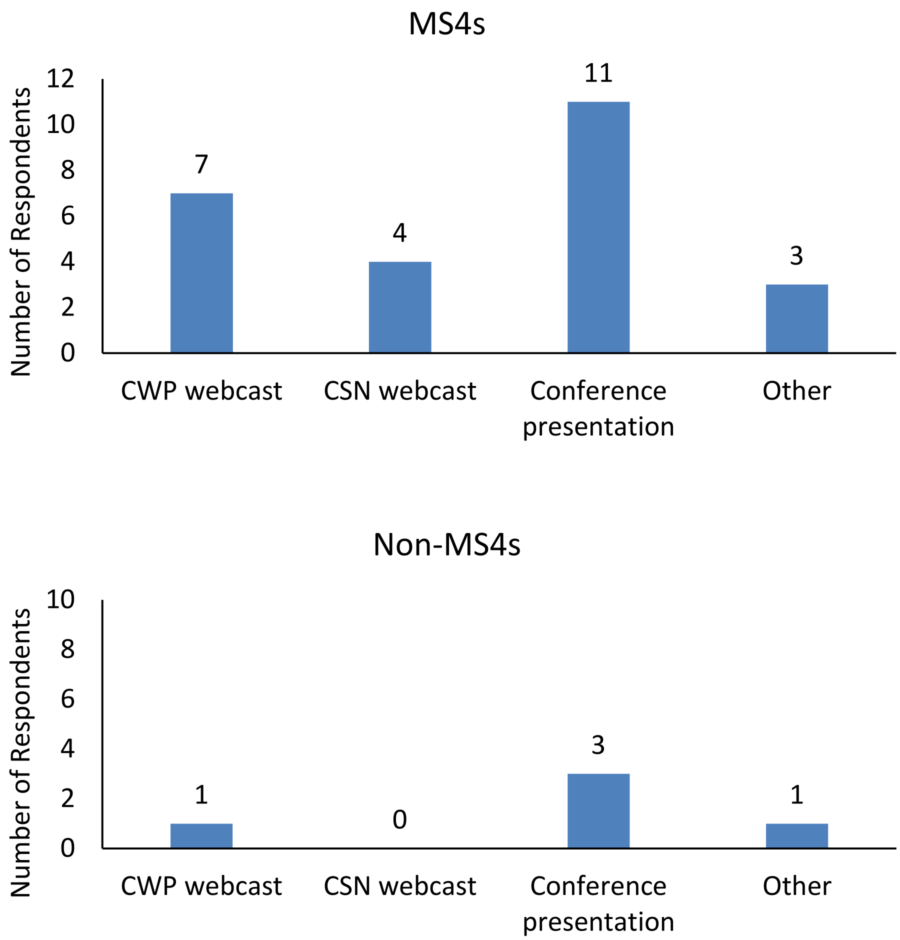
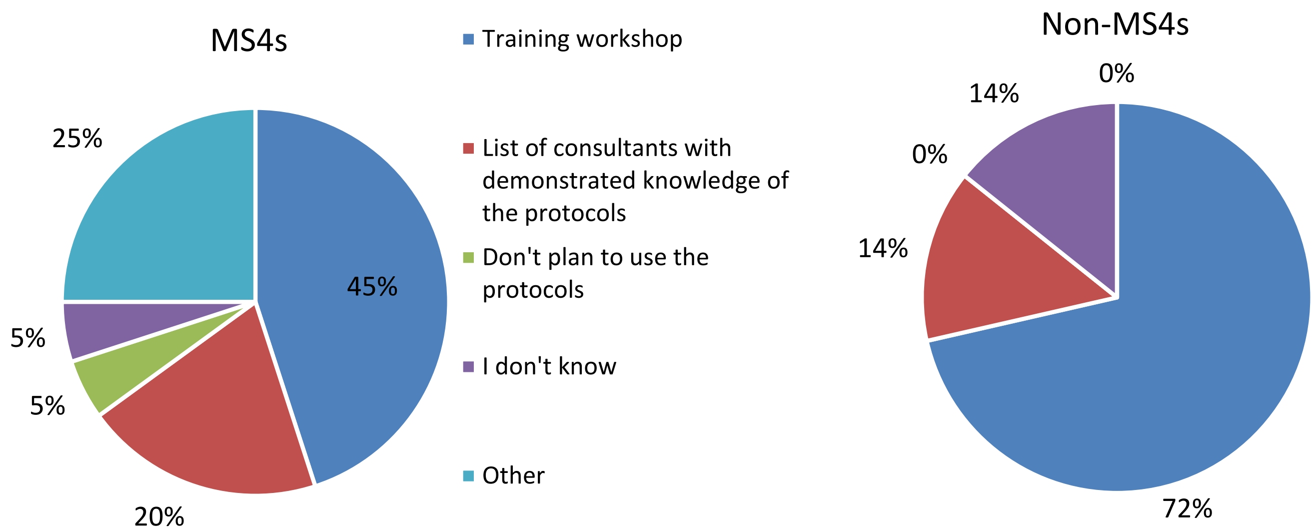


Figure 4-9. Stream Restoration Protocol Training Attendance Within the Chesapeake Bay Watershed.

The majority of MS4s (45%) and non-MS4s (72%) indicated that a training workshop would be the most beneficial for using the CBP stream restoration crediting protocols. An additional 20% of MS4s and 14% of non-MS4s indicated that a list of consultants with demonstrated knowledge of the protocols would be useful. Of the five MS4 respondents who responded “other,” the following responses were provided: lower monitoring costs, and concrete case studies showing the application of the protocols in various circumstances. One MS4 also indicated that the protocols are not applicable to all projects.

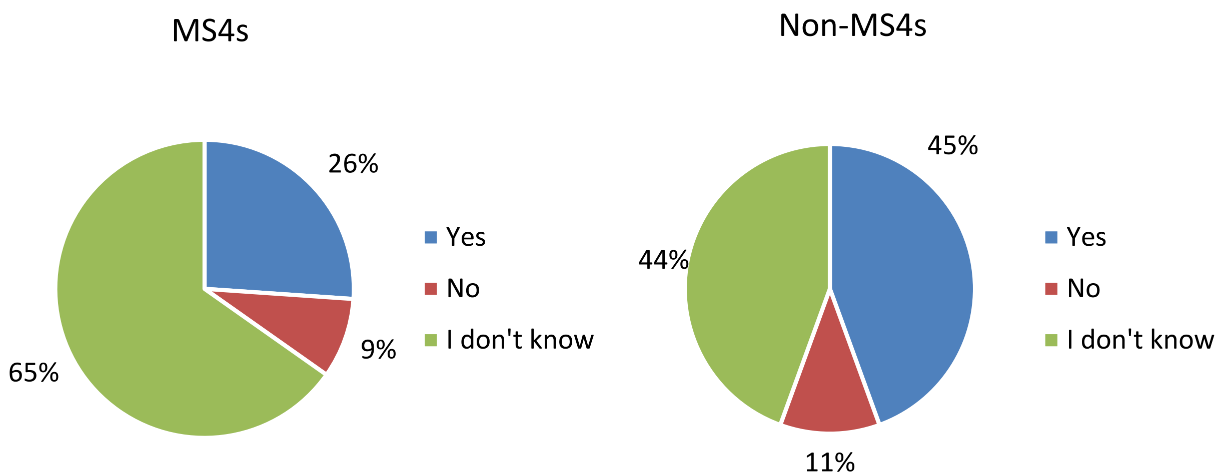


Resource	Number of MS4 Respondents	Number of Non-MS4 Respondents
Training workshop	9	5
List of consultants with demonstrated knowledge of the protocols	4	1
Don't plan to use the protocols	1	0
I don't know	1	1
Other	5	0

Figure 4-10. Most Beneficial Resources for Protocol Use Within the Chesapeake Bay Watershed.

4.1.5 WRF Stream Restoration Database

Of the 23 MS4 respondents, only one was aware of WRF's Stream Restoration Database and of the nine non-MS4 respondents, none were aware of the database. None of the respondents have either contributed studies to the database or used the results. The majority of MS4s (65%) indicated they were unsure if they would be willing to contribute to the database. However, 26% did note that they would be willing to contribute. The non-MS4 respondents were split equally (45% each) as to whether they would be willing to contribute or did not know. Six MS4 provided reasons for not wanting to contribute to the database, including the lack of monitoring studies to contribute, lack of knowledge about the database, and concern over potential costs. None of the non-MS4s provided reasons for not wanting to contribute to the database.



Willingness	Number of MS4 Respondents	Number of Non-MS4 Respondents
Yes	6	4
No	2	1
I don't know	15	4

Figure 4-11. Willingness to Contribute to WRF's Stream Restoration Database Within the Chesapeake Bay Watershed.

4.2 Survey of States and Municipalities Outside of the Chesapeake Bay Watershed

This survey was conducted of other states and municipalities outside of the Chesapeake Bay watershed that have adopted or are considering adopting stream crediting/trading programs that could benefit from the WRF Stream Restoration Crediting Guidance. The survey was similar to the previous survey described above, but focused on the other regions outside of the Chesapeake Bay watershed. The survey questions are provided in Attachment B and a spreadsheet of the survey responses is included in Attachment D.

The survey was distributed to states and municipalities outside of the Chesapeake Bay watershed through:

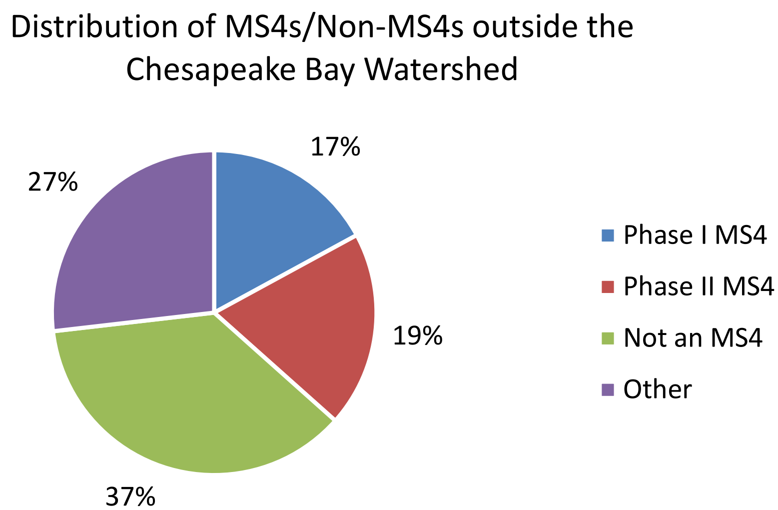
- Wright Water Engineers, Inc. distribution of the survey to their contacts.
- Water Resources Institute distribution of the survey to their stream restoration conference mailing list.
- List of 1,930 state and local government contacts across the country maintained by the Center.

A total of 59 initial survey responses were filtered as follows and resulted in a final response count of 41:

- Two duplicate entries were removed. These appear to be respondents that initially started the survey and returned at a later time to complete the survey through a new entry.
- One survey test response was removed.
- Eighteen responses were removed because they did not respond to the survey questions.

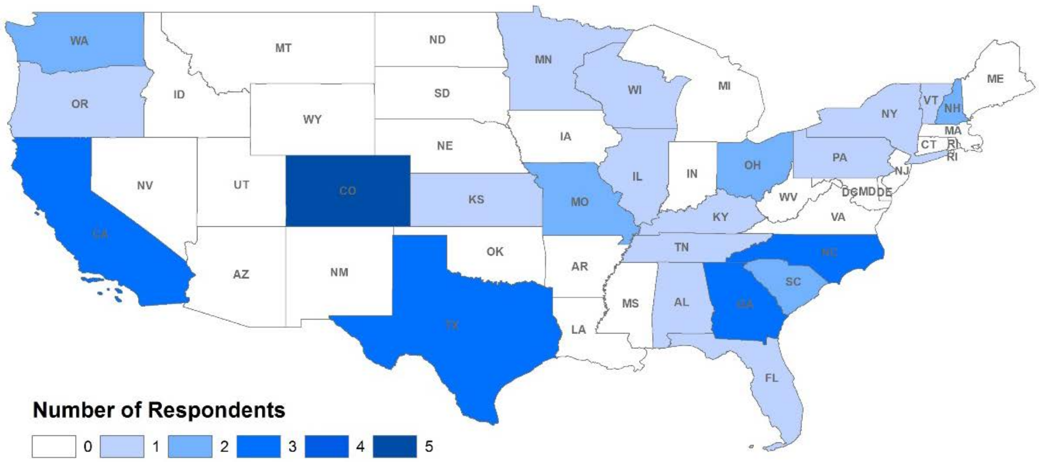
4.2.1 Respondents

Of the 41 responses to the survey of states and municipalities outside of the Chesapeake Bay watershed, 36% (15 respondents) were either Phase I or Phase II MS4s. The majority (64%) indicated they were not MS4s.



Organization Type	Number of Respondents
Phase I MS4	7
Phase II MS4	8
Not an MS4	15
Other	11

Figure 4-12. Distribution of Survey Respondents Outside of the Chesapeake Bay Watershed by Organization Type.



State	Number of Respondents
Alabama	1
California	3
Colorado	5
Florida	1
Georgia	3
Illinois	1
Kansas	1
Kentucky	1
Minnesota	1
Missouri	2
New Hampshire	2
New York	1
North Carolina	3
Ohio	2
Oregon	1
Pennsylvania	1
South Carolina	2
Tennessee	1
Texas	3
Vermont	1
Washington	2
Wisconsin	1

Figure 4-13. Distribution of Survey Respondents Outside of the Chesapeake Bay Watershed by State.

4.2.2 Number and Type of Stream Restoration Projects

Outside of the Chesapeake Bay watershed, the majority of both MS4s and non-MS4s have completed ten or fewer stream projects in the past five years. The average number of projects for the MS4 respondents indicating they do stream restoration was 19.3 projects, while the average for non-MS4s was 10.6 projects. Four MS4 and seven non-MS4 respondents indicated they have not done any stream restoration projects. The largest number of projects reported by MS4s was by Washington State Department of Transportation (100 projects), followed by the City of Austin, TX (50 projects). The largest number of projects reported by non-MS4s was by Five Smooth Stones Restoration in Colorado (40 projects) and the Missouri Department of Transportation (40 projects), followed by the Rondout Neversink Stream Management Program in NY (30 projects). Of the MS4s, all respondents reported total length of stream restoration projects over the past five years less than 25,000 linear feet. The non-MS4 responses were considerably more variable; however, most respondents indicated stream project lengths of 10,001-20,000 linear feet. The average total length of stream projects within the past five years for MS4 respondents was 8,979 linear feet, while the average for non-MS4s was 21,393 linear feet.

All of the MS4 respondents indicated fewer than 50 planned stream projects within the next five years. The majority (seven respondents) indicated they had from 1-10 planned projects, while five indicated they had no planned stream restoration projects. The City of Austin, TX reported the highest number of planned projects (50 projects), but indicated that the total length of these projects was only 20,000 linear feet, which averages to 400 linear feet per project. In comparison, the Southeast Metro Stormwater Authority in CO has a total projected length of six miles across 12 projects (average of 2,640 linear feet per project) and the Southeast Metro Stormwater Authority in NC has a total project length of 30,000 feet across three projects (average of 10,000 linear feet per project).

All of non-MS4 responses were fewer than 20 planned projects within the next five years. The majority (13 respondents) indicated they had from 1-10 planned projects, while six indicated they had no planned stream restoration projects. The Missouri Department of Transportation reported the highest number of planes projects (20 projects), but indicated that the total length of these projects was only about one mile, which averages to 264 linear feet per project. The greatest total length of planned stream restoration projects was by the Kentucky Department of Fish and Wildlife Resources who reported 100,000 feet planned over the next five years across 10 projects, which averages to 10,000 linear feet per project.

All of the MS4s and all of the non-MS4s except for two who responded they do stream restoration projects implement natural channel design projects. The second most common types of stream restoration are floodplain reconnection and channel reconfiguration for both MS4s and non-MS4s. Legacy sediment removal and regenerative stormwater conveyance were the least common type of stream restoration design implemented. Three MS4s responded with "other" types of stream projects typically implemented, specifying: erosion armoring, education, and fish passage barrier removal. Twelve non-MS4s responded with "other" typical types of stream projects, specifying: dry gulch stabilization, bank stabilization (two respondents), dam removal/modification (two respondents), process-based restoration, urban stream restoration, native vegetation enhancement, stream crossing improvements, fish habitat improvement, and plan reviews/permit approvals with local MS4s (two respondents).

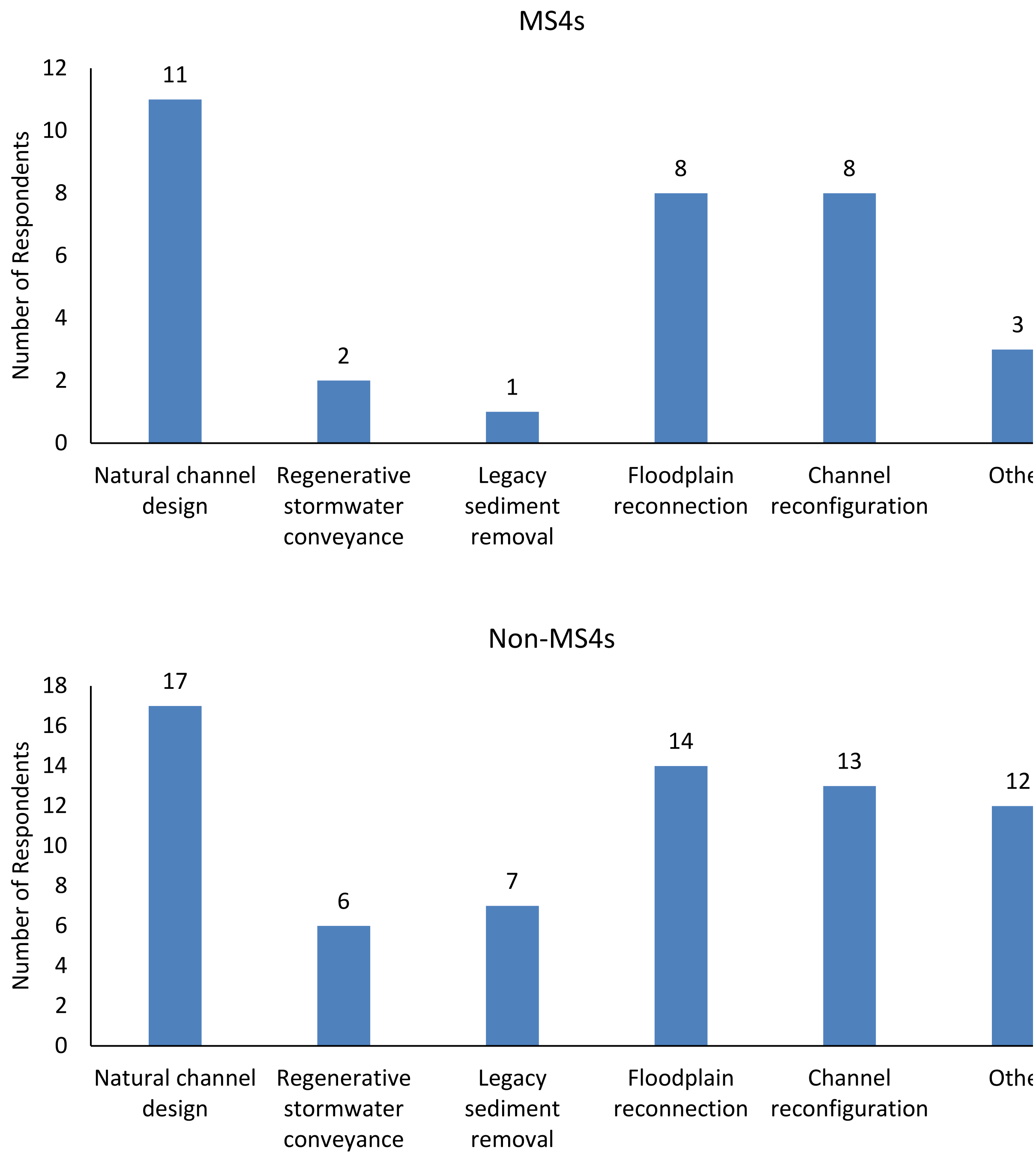


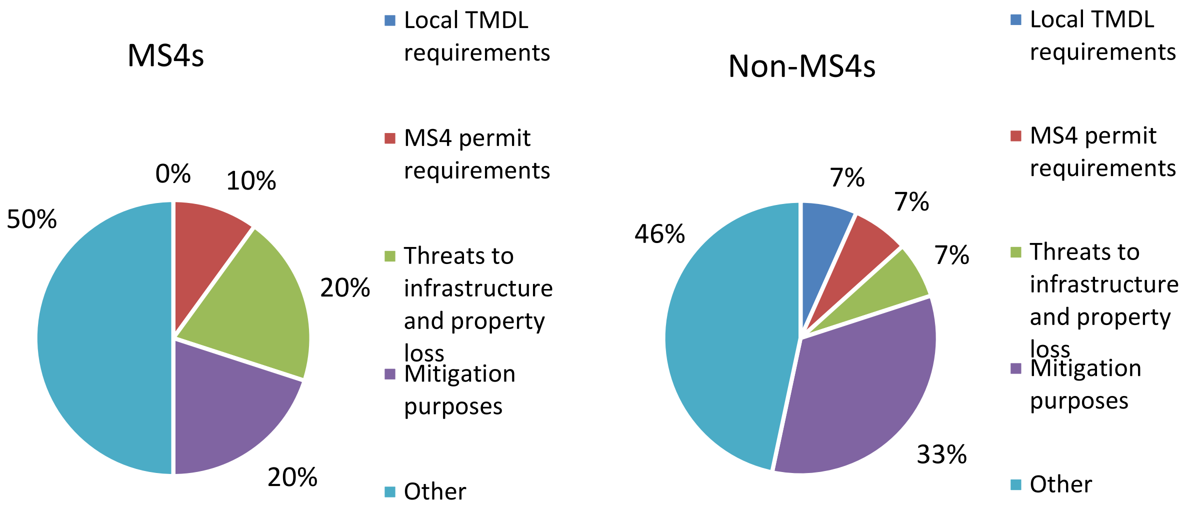
Figure 4-14. Types of Stream Restoration Projects Typically Implemented Outside of the Chesapeake Bay Watershed.

Of the eight MS4 respondents who typically do channel reconfiguration projects, seven indicated that it is done in combination with other project types like natural channel design or floodplain reconnection. All 13 of the non-MS4s who typically do channel reconfiguration projects indicated that is done in combination with other project types. Two MS4s responded that they do not typically do channel reconfiguration projects, however, one indicated that when they do it is part of other project types and one indicated that it is done solely as channel reconfiguration. Three non-MS4s that do not typically do channel reconfiguration projects indicated that when they do it is part of other project types. The majority of MS4s and non-MS4s that implement channel reconfiguration (56% and 47%, respectively) report that they typically reconfigure channels to a low degree (<25% of the total project length reconfigured). An additional 33% of MS4s and 27% of non-MS4s that implement channel reconfiguration report that they typically reconfigure channels to a high degree (>50% of the total project length reconfigured).

4.2.3 Identification of Projects and Reasons for Implementation

A variety of methods were provided for identifying stream restoration projects. Four out of 10 MS4s that responded conduct stream channel erosion/stability assessments to identify potential stream restoration locations. Two MS4s obtain restoration sites from watershed assessments and master plans and one is moving to a watershed planning process, but historically used a stream restoration ranking protocol based on site degradation and project feasibility. Two MS4s identify their restoration projects based on location on city-owned land. Fourteen non-MS4s provided responses. Four non-MS4s identify project locations based on watershed plans or transportation improvement plans. The others provided a variety of methods, including: opportunity based on partner requests, public interest, funding, and access; threats to infrastructure; bank erosion monitoring and sediment impact to streams; failing dams; and impacts to fish and habitat.

Twenty percent of MS4s reported mitigation purposes and an additional 20% reported threats to infrastructure and property loss as the primary reasons for implementing stream restoration projects. The majority MS4s respondents (50%) responded with “other” primary reasons, including water quality improvement, fish/salmon management and conservation, and watershed protection plan implementation. Thirty three percent of non-MS4s indicated mitigation purposes as the primary reason for implementing stream restoration projects. The majority of non-MS4 respondents (46%) responded with “other” primary reasons, including: channel stabilization; prevention of sediment from reaching reservoirs; NPDES Permit special conditions; managing and conserving fisheries; addressing a combination of threats to infrastructure, property loss, and habitat restoration; restoring designated uses and removing surface waters from the 303(d) list; and eliminating/reducing sources of nonpoint source pollution.

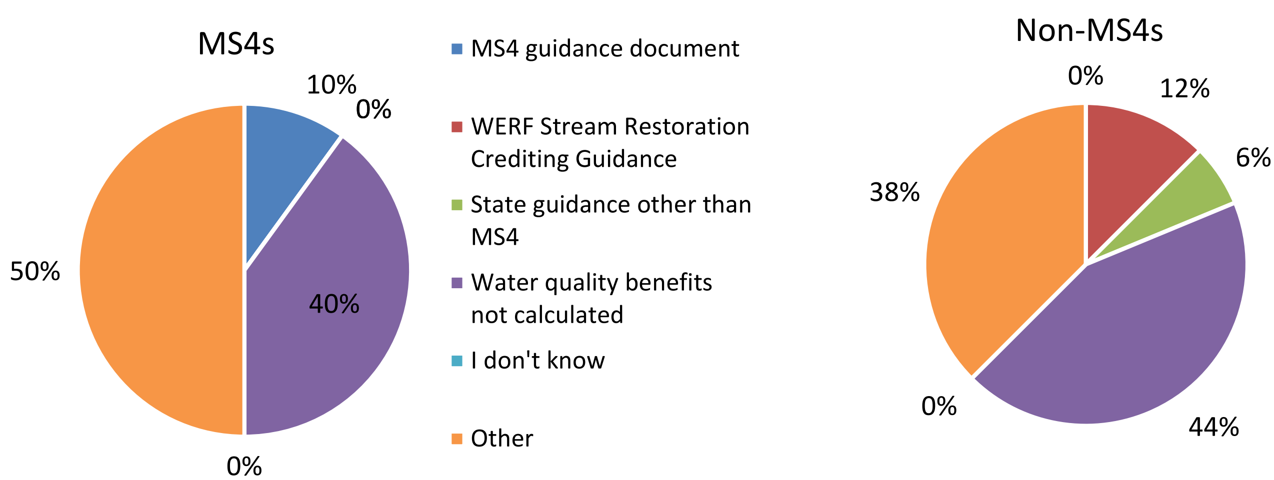


Reason for Stream Restoration Project Implementation	Number of MS4 Respondents	Number of Non-MS4 Respondents
Local TMDL requirements	0	1
MS4 permit requirements	1	1
Threats to infrastructure and property loss	2	1
Mitigation purposes	2	5
Other	5	7

Figure 4-15. Primary Reasons for Implementing Stream Restoration Projects Outside of the Chesapeake Bay Watershed.

4.2.4 Crediting Stream Restoration Projects

Forty percent of MS4s implementing stream restoration projects reported that they do not calculate water quality benefits. Half of the MS4s calculate water quality benefits using methods other than MS4 or state guidance or the WRF stream restoration crediting protocols, including calculations of stream channel sediment loss reduction, calculation of the reduction in pounds of phosphorous transported to a nutrient impaired water body as a result of channel reclamation, and use of both continuous monitoring and consultant guidance. Similar to MS4s, a large portion of non-MS4 respondents (44%) reported that they do not calculate water quality benefits. Two non-MS4 respondents from Wright Water Engineers indicated using the WRF stream restoration crediting protocols. Thirty eight percent calculate water quality benefits using methods other than MS4 or state guidance or WRF stream restoration crediting protocols, including the CBP stream restoration crediting protocols, mitigation credit protocols for Kentucky, calculations of sediment removal, measurement of increased index of biotic integrity and qualitative habitat evaluation index, and improvements in water quality parameters such as dissolved oxygen, and pre and post-restoration water quality monitoring and river and stream assessment techniques (particle size analyses, fish population assessments, cross-sections, etc.).



Method for Water Quality Benefit Calculation	Number of MS4 Respondents	Number of Non-MS4 Respondents
MS4 guidance document	1	0
WRF Stream Restoration Crediting Guidance	0	2
State guidance other than MS4	0	1
Water quality benefits not calculated	4	7
I don't know	0	0
Other	5	6

Figure 4-16. Methods for Water Quality Benefit Calculation of Stream Restoration Projects Outside of the Chesapeake Bay Watershed.

Of the MS4s and non-MS4s that calculate water quality benefits from stream restoration projects, the majority indicated sediment as their primary pollutant of concern (seven MS4 and seven non-MS4 respondents). Phosphorus and nitrogen were also noted as pollutants of concern. One non-MS4 reported metals as another pollutant of concern. Although not a pollutant, one non-MS4 also reported aquatic life improvement as a concern.

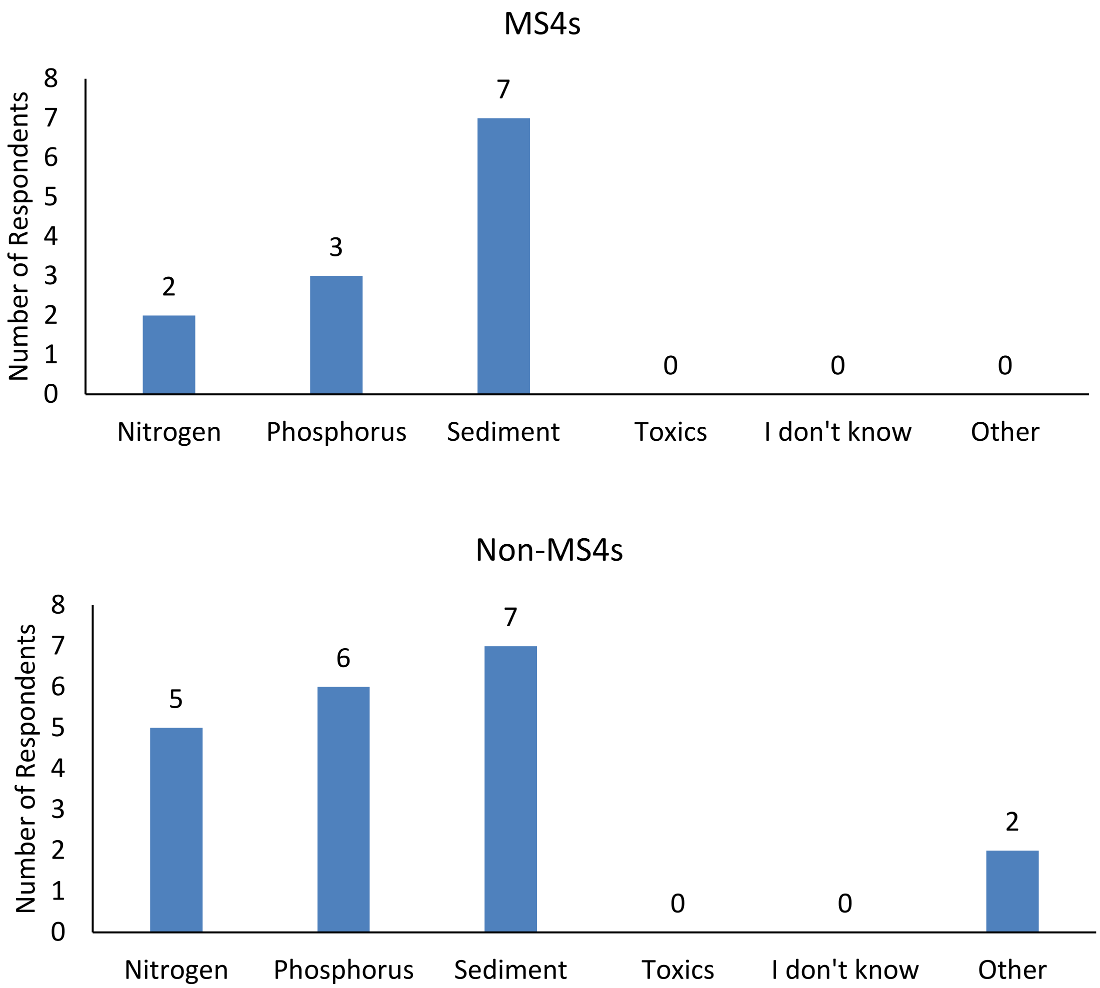


Figure 4-17. Primary Pollutants of Concern Outside of the Chesapeake Bay Watershed.

One MS4 and six non-MS4s responded that their state or organization has adopted a stream restoration crediting or trading program. These programs include:

- Tennessee Stream Mitigation Program (TSMP) – The TSMP is a statewide in-lieu-fee program that was created to offset physical impacts associated with water quality permits issued by the State of Tennessee and the U.S. Army Corps of Engineers. Since 2003, the TSMP has worked to provide meaningful compensatory mitigation that is both successful and cost effective. To do this, the TSMP maintains a small, yet highly trained staff of professionals that are able to identify and implement large scale projects that are beneficial on a watershed level. http://tsmp.us/
- Colorado – Colorado has trading regulations, but they have not yet been applied to stream restoration projects. Stream restoration is not an allowable BMP for meeting MS4 permit

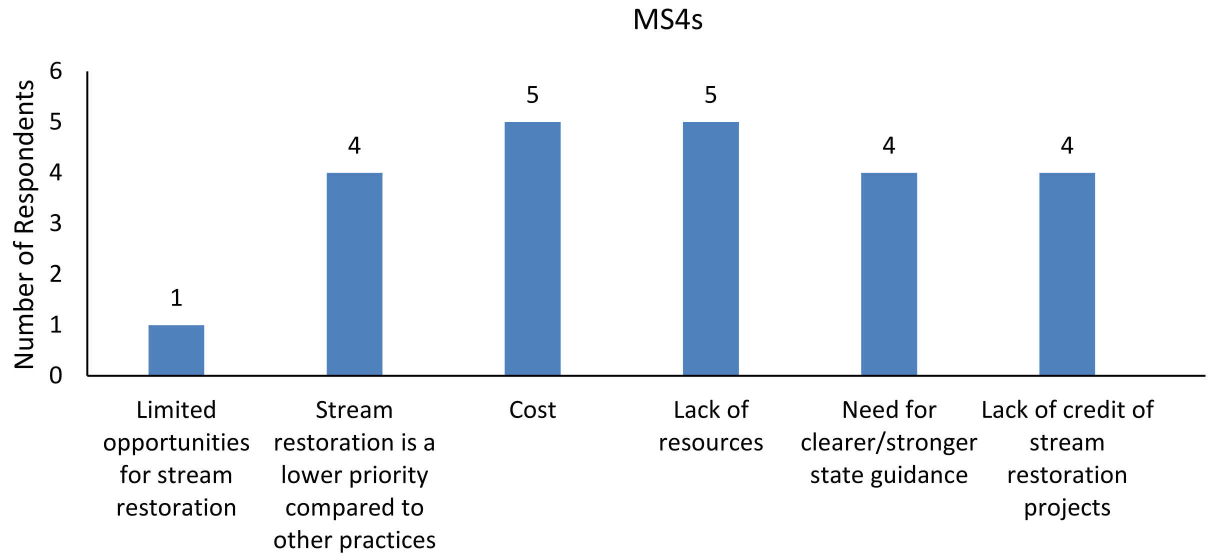
requirements for water quality. The U.S. Army Corps of Engineers and the Environmental Protection Agency are in the process of developing a Stream Quantification Tool (SQT) and Mitigation Rules for Colorado. The purpose of the SQT is to calculate functional loss and lift associated with stream impacts and restoration projects. https://stream-mechanics.com/stream-functions-pyramid-framework/. The WRF stream restoration crediting guidance is currently being used on a pilot project in Denver.

- Savannah, GA – Compensatory mitigation for unavoidable impacts to waters of the united states under section 404 of the Clean Water Act: http://www.sas.usace.army.mil/Missions/Regulatory/Mitigation/Banks/
- New Hampshire – The Aquatic Resource Mitigation Program receives payments for stream impacts which are then aggregated by watershed and provided to grantees from a competitive grant round. Impacts are paid for on a linear feet basis, and credits are provided in the same manner. https://www.des.nh.gov/organization/divisions/water/wetlands/wmp/index.htm http://www.nae.usace.army.mil/Missions/Regulatory/Mitigation/In-Lieu-Fee-Programs/NH/
- San Jacinto River Watershed, California – The Conditional Waiver of Waste Discharge Requirements for Agricultural Discharges approved in April 2017 allows for the formation of water quality trading programs in order to help meet nutrient TMDL requirements for Canyon Lake and Lake Elsinore. https://www.waterboards.ca.gov/santaana/water_issues/programs/planning/CWAD/CWAD_new_date_Revision.pdf

One MS4 and four non-MS4s responded that their state or organization is considering adopting a stream restoration crediting or trading program.

- Southeast Metropolitan Stormwater Authority in NC – Nothing has been developed yet but they would like to assign pollutant reduction credits to stream restoration for the purpose of prioritizing upland BMPs and stream restoration based on $/lb/yr of sediment removed.
- The Conservation Foundation/DuPage River Salt Creek Workgroup, Illinois – They are in preliminary stages of the development of a nutrient and stream restoration practice trading program in the DuPage River and Salt Creek watersheds. They have hired the team of TetraTech, Kaiser and Associates, ABT, and Earth and Water Group to help lead this framework development. Information on the program will be available on their website at http://drscw.org/ as it becomes available.
- Oregon – The Oregon Department of Environmental Quality (DEQ) Commission approved rules establishing a voluntary water quality trading program to facilitate pollution reduction and protect the quality of Oregon's waterways in December 2015. DEQ has allowed trades that involve riparian shade restoration to improve stream temperatures, flow augmentation, and trading of BOD and ammonia between wastewater treatment plants. DEQ is hoping to expand its trading program to include nutrient and sediment trading as well as trades involving aquatic habitat and floodplain restoration to reduce the impacts of warm stream temperatures. http://www.oregon.gov/deq/wq/wqpermits/Pages/Trading.aspx

The challenges faced by MS4s and non-MS4s for adopting a stream restoration crediting or trading program covered the range of options, including stream restoration being a lower priority, cost, lack of resources, need for guidance, and lack of credit of stream restoration projects. Limited opportunities for stream restoration projects was not identified as a barrier. Three of the MS4 respondents indicated "other" major challenges preventing their adoption of a stream restoration crediting or trading program. One of those respondents was not sure if their state had a program, one stated there was no demand and that their projects are predominantly grant funded, and one explained how the conflicting priorities of their stakeholders made program adoption difficult. Six of the non-MS4 respondents also indicated "other" major challenges, including no credit requirement, lack of knowledge, complex permitting, and stream restoration not being a part of their TMDL's Wasteload Allocation.



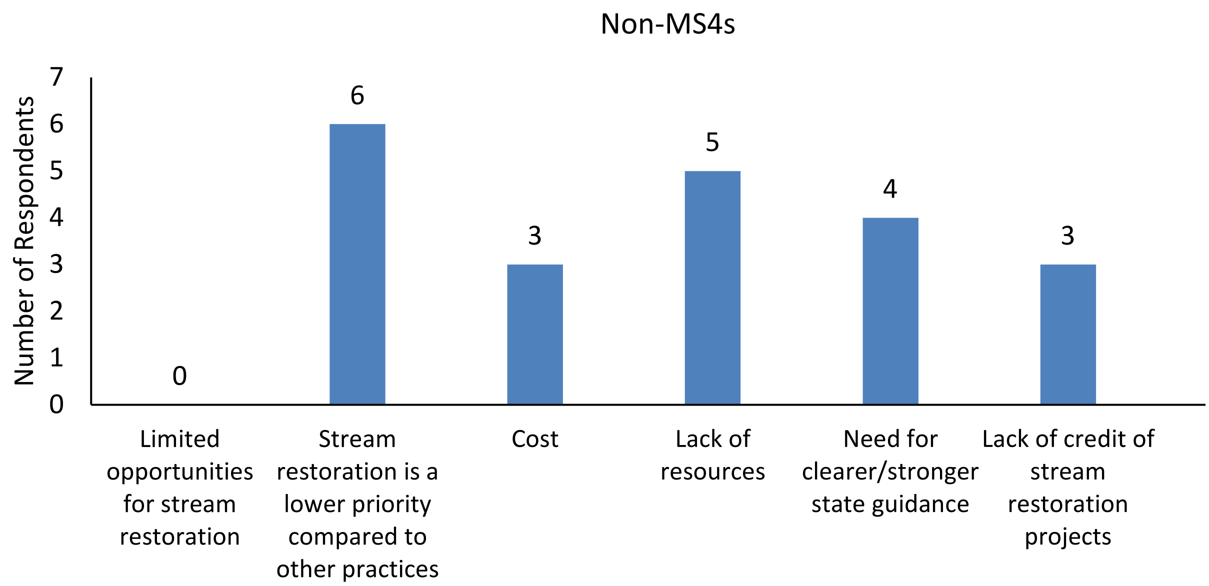
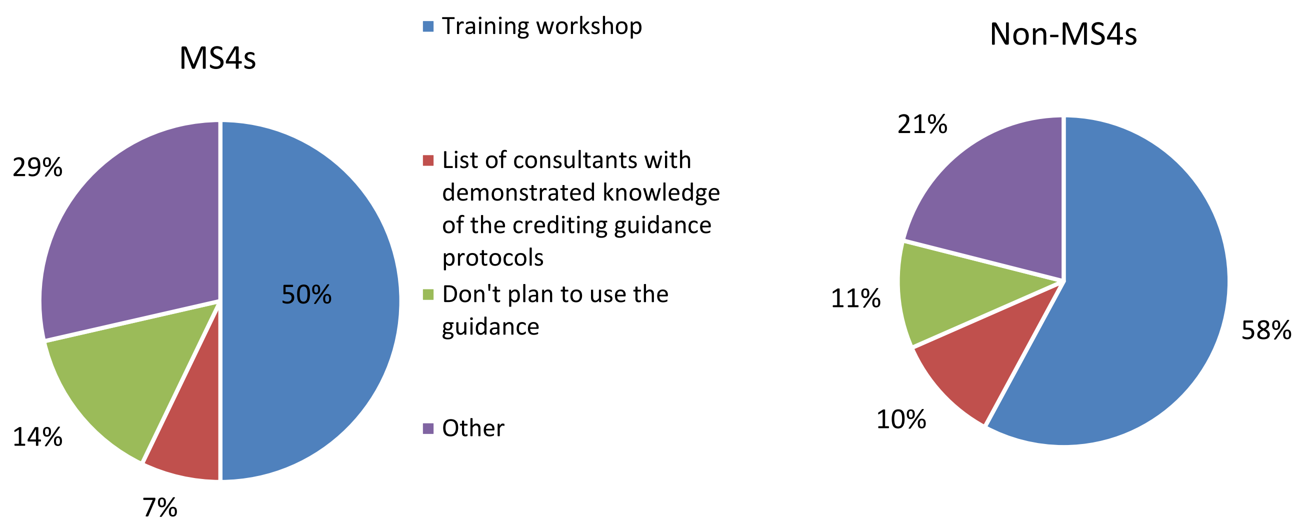


Figure 4-18. Challenges Preventing the Adoption of a Stream Restoration Crediting or Trading Program Outside of the Chesapeake Bay Watershed.

Half of the MS4 respondents were not aware of either the CBP stream restoration crediting protocols or the WRF stream restoration crediting guidance. More than half of the non-MS4 respondents were also not aware of either the CBP or WRF crediting guidance. Of the five MS4s that responded they were aware of the WRF stream restoration crediting guidance, none of them have used the guidance. Of the six non-MS4s that responded they were aware of the WRF guidance, only two from Wright Water Engineers have used it. The reasons provided by MS4s that have not used the WRF guidance include: being unsure of the methodology, being unaware of the crediting guidance or just learning about it, a focus on fish habitat restoration instead of water quality benefit calculation, and a lack of regulatory drivers. The non-MS4s that are not using the WRF guidance indicated that they either don't have an existing trading program or are currently discussing its use for program development (The Conservation Foundation/DuPage River Salt Creek Workgroup).

Twenty nine percent of the MS4 respondents were interested in using the crediting guidance in the future and 29% also responded that they did not know. One respondent said they were not interested. Five of the 14 MS4 respondents provided alternate responses, which were split between a concern for state acknowledgement of the guidance and an interest in learning more about it first. Of the non-MS4 respondents, 20% were interested in using the guidance in the future, while the majority (65%) did not know. Only one respondent said they were not interested in using the guidance, and two respondents specified that they would have to do more research prior to using it.

The majority of MS4s (50%) and non-MS4s (58%) indicated that a training workshop would be the most beneficial resource for using the WRF stream restoration crediting guidance. Of the four MS4s who provided alternate responses to this question, one said it was straightforward enough as is, one requested an example of a credited project in Colorado, one said they would like to quantify the benefits of projects to compare with other CIPs, and one detailed the need for a change in approach on the West Coast from site-based restoration to more holistic approaches. Of the four non-MS4s who provided alternate responses, one said they did not need training since they developed the guidance, one requested a low-cost online training course, one requested a manual for self-learning, and one requested examples and workbooks based on the guidance.



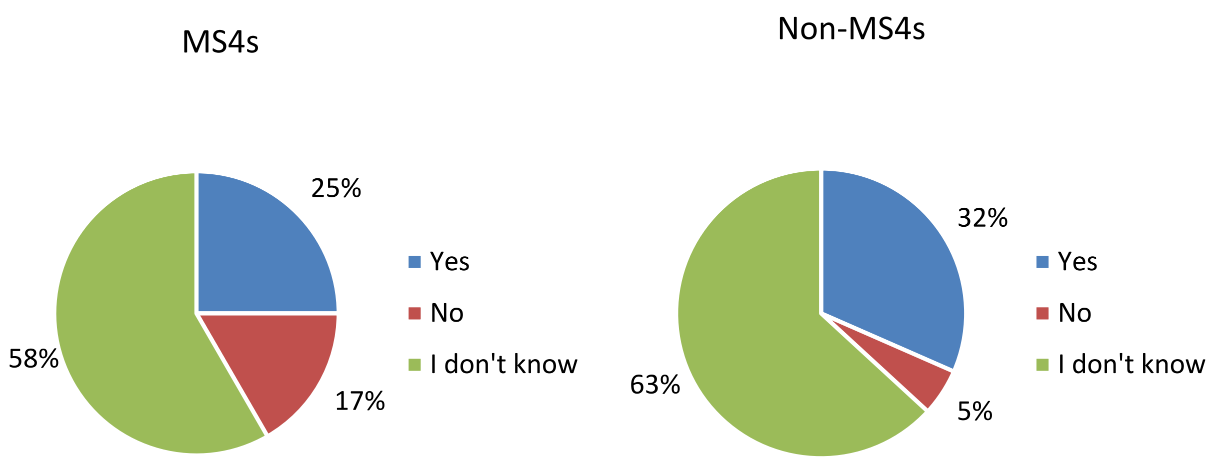
Resource	Number of MS4 Respondents	Number of Non-MS4 Respondents
Training workshop	7	11
List of consultants with demonstrated knowledge of the crediting guidance protocols	1	2
Don't plan to use the guidance	2	2
Other	4	4

Figure 4-19. Most Beneficial Resource for Use of WRF Stream Restoration Crediting Guidance Outside of the Chesapeake Bay Watershed.

4.2.5 WRF Stream Restoration Database

Out of 13 MS4 respondents, only four were aware of WRF's Stream Restoration Database. Similarly, out of 19 non-MS4 respondents, only three were aware of the database. None of the MS4s have contributed to the database and only one non-MS4 (Wright Water Engineers) has contributed. Only one MS4 (Washington State Department of Transportation) and one non-MS4 (Wright Water Engineers) reported using the database to inform their work.

Twenty five percent of the MS4 respondents and 32% of the non-MS4 respondents indicated that they would be willing to contribute to the WRF database. Most of the other respondents were unsure. Those that indicated they were not willing to contribute to the database noted that either had no monitoring studies or lacked the time and resources.



Willingness	Number of MS4 Respondents	Number of Non-MS4 Respondents
Yes	3	6
No	2	1
I don't know	7	12

Figure 4-20. Willingness to Contribute to WRF's Stream Restoration Database Outside of the Chesapeake Bay Watershed.

CHAPTER 5

Summary and Recommendations

The WRF Stream Restoration Crediting Guidance has been available since 2016, yet it is unknown how many WRF subscribers have implemented the recommendations. States and municipalities within the Chesapeake Bay watershed have begun implementing the CBP stream restoration protocols found in the WRF report since they were first approved in 2014. The purpose of this research project is to highlight the experiences that municipalities have had with the implementation of the stream restoration protocols across the Chesapeake Bay Watershed at the state and local municipality level, as well as the feedback from states outside of the Chesapeake Bay watershed who have adopted or are considering adopting the WRF guidance. The results of this project have yielded valuable information about the current and potential future use of the crediting protocols, including the need for protocol adaptability, establishment of crediting and trading programs, the needs of potential users, and a proposed education and outreach campaign. This chapter describes a summary of the main findings of this report and the next steps recommended for WRF, including:

1. Continue to evaluate and refine the crediting protocols by following up with results of the monitoring studies included in Table 2-1, staying informed of the CBP's technical groups to improve the protocols, and attending stream restoration conferences and meetings.
2. Monitor the trading programs in Virginia and Maryland to learn from their incorporation of stream restoration as part of the programs and consider outreach about the stream restoration crediting guidance to the states outside of the Chesapeake Bay that are in the beginning stages of their own trading programs.
3. Establish an education and outreach campaign initially focusing on state and regulatory agencies and providing oversight and a process by which the protocols can be adapted to specific conditions or interests in their region.
4. Provide workshops and other venues to provide training to users of the crediting protocols, such as workshops, webcasts, and a dedicated website with resources and case studies.

5.1 Stream Restoration Crediting Protocol Adaptability

The CBP stream restoration crediting protocols included in the WRF guidance were based on the best available information at the time of their development. It was the intention of the CBP Stream Restoration Expert Panel to incentivize monitoring to collect data needed to improve the protocols at some point in the future. After review of the monitoring case studies within the Chesapeake Bay watershed, it was difficult to find statistically robust monitoring studies that included upstream-downstream and before and after paired watershed monitoring designs because they are expensive, take time and training. Funding options are limited as the Chesapeake Bay Trust is the only source of funding within the Chesapeake Bay watershed that will pay for statistically robust monitoring designs through their Restoration Grant Program (https://cbtrust.org/grants/restoration-research/). Further, since the protocols were developed in 2014, there has been insufficient time for organizations to mobilize and collect monitoring data that would provide statistically meaningful results. Most of the studies identified addressed only certain questions (e.g., Frederick County, MD and District of Columbia) that would improve the amount of sediment and nutrient load reduction credit they would receive and were not specifically designed to test the accuracy of the protocols except for the 50% restoration efficiency for Protocol 1 which is the most widely used of the protocols. However, there are several studies identified that while not specifically designed to validate the protocols should have results that can be used for this purpose. Most of the studies included in Table 2-1 are still underway and results are pending. WRF should follow up with the study contacts upon completion to obtain the results and consider their use as part of a strategy to continually adapt the crediting protocols based on the best available data. In addition, the CBP's Urban Stormwater Work Group (USWG) recently established technical groups to improve the stream restoration protocols. WRF should reach-out to the chair of the USWG to determine the best way to stay informed of any potential adjustments to the CBP crediting protocols (https://www.chesapeakebay.net/channel_files/27680/attach_g_final_stream_team_memo.pdf).

The literature review was conducted to help gain a better understanding of the benefits and limitations of watershed processes and channel reconfiguration as practices for restoring streams. While controlling watershed processes prior to degradation of the stream intuitively makes sense, it was not specifically included in the WRF stream restoration crediting guidance because of the limited quantifiable evidence on its effect on stream processes. Likewise, restoring streams through channel reconfiguration was not incorporated into the WRF crediting guidance. Channel reconfiguration is typically associated with other stream restoration techniques, making it difficult to isolate the pollutant removal benefits of channel changes alone. The literature review found that the control of watershed processes and channel reconfiguration remain a needed area of research and WRF should continue to exclude these as standalone strategies from the crediting guidance until future research suggests otherwise.

WRF should consider staying involved with the stream restoration community through attendance at conferences and meetings of stream restoration organizations. This would provide WRF the opportunity to keep abreast of the most recent studies and findings in the stream restoration field, as well as share knowledge and provide outreach about the stream restoration crediting guidance. Table 5-1 provides links to various conferences and organizations that WRF may consider as resources.

Table 5-1. Stream Restoration Conferences and Organizations.

Conference/Organization	Weblink
American Water Resources Association	https://www.awra.org/
Ecostream Stream Ecology and Restoration Conference	https://www.bae.ncsu.edu/workshops-conferences/ecostream-conference/
Maryland Stream Restoration Association	https://marylandstreamrestorationassociation.org/
Mid-Atlantic Stream Restoration Conference	https://midatlanticstream.org/
River Restoration Northwest	http://www.rrnw.org/
Rocky Mountain Stream Restoration Conference	https://rockymountainstream.org/
Southwest Stream and Wetland Restoration Conference	https://southweststream.squarespace.com/
Upper Midwest Stream Restoration Symposium	http://prrsum.umn.edu/symposium/2019-upper-midwest-stream-restoration-symposium

5.2 Crediting and Trading Programs

Stream restoration projects may provide pollutant trading and mitigation opportunities where water quality regulatory programs require pollutant reduction within a watershed. Crediting and trading programs within the Chesapeake Bay watershed were reviewed. In addition, the survey respondents indicated several programs outside of the Chesapeake Bay watershed that have either been implemented or are in the process of being developed. These examples can help utilities and municipalities in other states/regions learn how to apply the crediting guidance to implement stream restoration/trading programs.

Within the Chesapeake Bay watershed, states and municipalities are required to use the CBP crediting protocols for compliance with the Chesapeake Bay TMDL. Maryland, Pennsylvania, and Virginia all have drafted guidance for MS4 that refer to the CBP crediting protocols for stream restoration. The majority of survey respondents within the Chesapeake Bay watershed are using the CBP stream restoration crediting protocols or MS4 guidance documents which refer to the protocols to calculate water quality benefits from stream restoration projects. Regulatory requirements drive the need for crediting stream restoration projects, with the majority of MS4s indicating permit requirements and the Chesapeake Bay TMDL as the primary reason for implementation of stream restoration projects.

In comparison , most survey respondents outside of the Chesapeake Bay watershed that are implementing stream restoration projects reported that they do not calculate water quality benefits. Of those that do, none (except two respondents from Wright Water Engineers) use the WRF stream restoration crediting guidance. The majority of respondents indicated they were not aware of either the CBP stream restoration crediting protocols or the WRF stream restoration crediting guidance. The ones that are aware are not using the guidance due to being unsure of the methodology, a focus other than water quality benefits, and a lack of regulatory drivers.

In terms of trading programs, Virginia is the only state within the Chesapeake Bay watershed that utilizes the CBP crediting protocols as part of its Chesapeake Bay Watershed Nutrient Credit Exchange Program. As of March 2017, there have been six applications for stream restoration to Virginia's nonpoint source nutrient bank and there is currently only one stream restoration project to date listed in Virginia's Nutrient Credit Registry. Maryland's trading program is currently under development and a crediting method as part of its draft guidance for relating stream restoration to impervious cover equivalency for purposes of calculating progress towards meeting MS4 permit. MDE has indicated that the crediting method will likely be changed to align with the protocols developed for the Chesapeake Bay and expects to finalize the Trading Program by the Fall of 2018. Pennsylvania's trading program is not designed to include MS4s or the urban sector and no stream restoration projects have been used to generate credits. Although Pennsylvania does not currently have a trading program for MS4s, the PA DEP has provided guidance to Phase II MS4s that would allow for offsets. For those municipalities within the Chesapeake Bay Watershed, stream restoration projects must follow the CBP crediting protocols.

Most stream restoration crediting or trading programs that survey respondents reported outside of the Chesapeake Bay watershed were based on stream restoration mitigation, including programs in Tennessee, Savannah GA, New Hampshire, and Louisville KY. The development of trading programs is currently underway in Colorado (including a pilot of the WRF stream restoration crediting guidance in Denver), the Southeast Metropolitan Stormwater Authority in NC, the Conservation Foundation/DuPage River Salt Creek Workgroup in Illinois, and in Oregon. Survey respondents outside the Chesapeake Bay watershed reported a variety of challenges for adopting a stream restoration crediting or trading program, including stream restoration being a lower priority, cost, lack of resources, need for guidance, no credit requirement, complex permitting, and stream restoration not being part of TMDL wasteload allocations. WRF should closely monitor the trading programs in Virginia and Maryland to learn from their incorporation of stream restoration as part of the programs. WRF should also consider outreach about the stream restoration crediting guidance to the states outside of the Chesapeake Bay that are in the beginning stages of their own trading programs and have the necessary regulatory drivers.

5.3 User Needs and Suggested Education and Outreach Approach

Within the Chesapeake Bay watershed, a third of the MS4 reported that they don't use the stream restoration protocols for numerous reasons, including having TMDLs that focus on pollutants other than nutrients and sediments, confusion over how the protocols apply to the types of projects they do, and that the protocols are too complicated. Outside of the Chesapeake Bay watershed, survey respondents were divided about whether they'd be interested in using the WRF stream restoration crediting guidance in the future. There is a concern for state acknowledgement of the guidance first and an interest in learning more about the guidance first.

The majority of survey respondents from both inside and outside the Chesapeake Bay watershed indicated that a training workshop would be the most beneficial for using the stream restoration crediting protocols. In addition, 20% of MS4s within the Chesapeake Bay watershed indicated that a list of consultants with demonstrated knowledge of the protocols would be useful. WRF should consider a targeted outreach and education campaign for the WRF stream restoration crediting guidance that first focuses on state agencies. Further outreach and education of municipal agencies would be beneficial after the states are aware of the guidance and support its use as an acceptable crediting application.

WRF should also consider an education and outreach campaign for use of the WRF Stream Restoration Database. Of the survey respondents within the Chesapeake Bay watershed, only one was aware of the database. Similarly, a majority of survey respondents outside of the Chesapeake Bay watershed were also not aware of the database and none reported using or contributing to the database (beyond Wright Water Engineers). Most respondents were unsure if they'd be willing to contribute in the future due to the lack of monitoring studies to contribute, lack of knowledge about the database, lack of time, and concern over potential costs.

WRF should utilize a variety of education and outreach strategies with an initial primary focus on direct outreach to states, utilities and regulatory agencies. The survey respondents indicated that they'd like to have approval from these agencies prior to adopting the stream restoration crediting guidance. Education of these agencies could have a trickle-down effect to the municipalities that rely on them for guidance. The states and regulatory agencies may want to adapt the protocols to specific conditions or interests in their region, such as the proposed adaptation of the crediting protocols proposed by North Carolina Sea Grant and North Carolina State University for North Carolina. In this case, WRF could help provide oversight and a process by which this can be accomplished.

After the stream restoration crediting programs are accepted for use by the states, municipalities, utilities and regulatory agencies, the next education and outreach strategy should focus on workshops and other venues to provide training, such as webcasts and a dedicated website with resources and case studies. Within the Chesapeake Bay watershed, the Center for Watershed Protection and the Chesapeake Stormwater Network are the only organizations known to have provided training to date. These organizations could potentially assist with trainings outside of the Chesapeake Bay watershed.

APPENDIX A

Inside the Chesapeake Bay Watershed Survey Questions

Survey of States and Municipalities within the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

The Water Environment & Reuse Foundation (now known as The Water Research Foundation) recently awarded a contract to the Center for Watershed Protection (Center) to survey states and municipalities regarding their use or possible interest in crediting guidance for stream restoration projects developed by WE&RF in 2016, as well as to review monitoring studies in the Chesapeake Bay Watershed that might validate or suggest improvements to the monitoring guidance. The WE&RF Stream Restoration Crediting Guidance includes stream restoration crediting protocols developed for the Chesapeake Bay region and provides a technical framework for quantifying water quality benefits of a specific suite of stream restoration practices. This research project will highlight experiences that utilities and municipalities have had with stream restoration protocols across the Chesapeake Bay watershed, as well as states outside of the Chesapeake Bay watershed that have adopted or are considering adopting stream crediting/trading programs that could benefit from the WE&RF Stream Restoration Crediting Guidance.

We'd like to request that you complete this ten-minute survey about your experience with the WE&RF or Chesapeake Bay stream crediting protocols. As a token of our appreciation, everyone who completes the survey will be entered into a drawing for a free Center-sponsored webcast of your choice (a $159 value).

Survey of States and Municipalities within the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

Organizational Background

1. Name

2. Email Address

3. Phone Number

4. Organization Name

5. State

6. County

7. Is your organization an MS4?

- Yes, Phase I MS4
- Yes, Phase II MS4
- No, not an MS4
- Other (please specify)

Survey of States and Municipalities within the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

Stream Restoration Background

8. What is the total number of stream restoration projects your organization has implemented in the past 4 years since the implementation of the Chesapeake Bay Program stream restoration crediting protocols? Please provide your best estimate.

9. What is the total length of stream restoration projects your organization has implemented in the past 4 years? Please provide your best estimate.

10. How many additional stream restoration projects does your organization have planned through 2025? Please provide your best estimate.

11. What is the total additional length of stream restoration projects your organization has planned through 2025? Please provide your best estimate.

12. What type(s) of stream restoration projects does your organization typically implement? Select all that apply.

- [ ] Natural channel design
- [ ] Regenerative stormwater conveyance
- [ ] Legacy sediment removal
- [ ] Floodplain reconnection
- [ ] Channel reconfiguration
- [ ] We don't do stream restoration
- [ ] Other (please specify)

Survey of States and Municipalities within the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

Stream Restoration Background

13. When implementing channel reconfiguration projects, are they done solely as channel reconfiguration or in combination with other project types like natural channel design or floodplain reconnection?

- ○ Solely channel reconfiguration
- ○ Done in conjunction with other project types
- ○ I don't know
- ○ We don't do channel reconfiguration
- ○ Other (please specify)

14. To what degree does your organization typically reconfigure the channel?

- ◯ Low (<25% of the total project length reconfigured)
- ◯ Medium (25%-50% of the total project length reconfigured)
- ◯ High (>50% of the total project length reconfigured)
- ◯ I don't know
- ◯ We don't do channel reconfiguration
- ◯ Other (please specify)

Stream Restoration Background

15. How does your organization identify locations for your stream restoration projects? Please describe.

16. What is your organization's primary reason for implementing stream restoration projects? Select one.

- ◯ Local TMDL requirements
- ◯ Chesapeake Bay TMDL requirements
- ◯ MS4 permit requirements
- ◯ Threats to infrastructure and property loss
- ◯ Mitigation purposes
- ◯ Other (please specify)

17. How does your organization currently calculate water quality benefits from your stream restoration projects?

- MS4 Guidance Document
- State guidance other than MS4
- CBP Stream Restoration Protocols
- Water quality benefits not calculated
- I don't know
- Other (please specify)

Stream Restoration Crediting Protocols

18. Is your organization aware of the CBP Stream Restoration Expert Panel recommendations?

- Yes
- No
- I don't know

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Survey of States and Municipalities within the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

Stream Restoration Crediting Protocols

19. Is your organization aware of the WE&RF's Stream Restoration Crediting Guidance, which includes the CBP Stream Restoration Expert Panel recommendations?

- Yes
- No
- I don't know

20. Has your organization used the Chesapeake Bay Program stream restoration protocols (Protocols 1, 2, and/or 3)?

- ◯ Yes, for planning purposes to estimate credits
- ◯ Yes, for calculating credit for constructed projects
- ◯ Yes, for both planning purposes and constructed projects
- ◯ No
- ◯ I don't know

Survey of States and Municipalities within the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

Stream Restoration Crediting Protocols

21. Why hasn’t your organization used the stream restoration protocols? Select all that apply.

- ◯ It's too complicated
- ◯ TMDLs focused on pollutants other than nutrients and sediment
- ◯ Unable to collect data needed for protocols
- ◯ Unsure of methodology
- ◯ Only use the default rate
- ◯ I don't know
- ◯ Other (please specify)

22. Is your organization interested in using the stream restoration protocols in the future?

- ◯ Yes
- ◯ No
- ◯ I don't know
- ◯ Other (please specify)

Stream Restoration Crediting Protocols

23. For how many projects has your organization used the Chesapeake Bay Program stream restoration protocols? If you don't know, please leave the text box blank and move on to the next question.

Planning Projects

Constructed Projects

24. If your organization has used Protocol 1, was a Bank and Nonpoint Source Consequences of Sediment (BANCS) assessment conducted, monitoring, or both?

- BANCS assessment only
- Monitoring only
- BANCS assessment and monitoring
- Historical photo comparison
- I don't know
- Other (please specify)

25. Please describe your organization's monitoring approach for Protocol 1. In your response, please include information on how the monitoring sites were selected, frequency of measurements, length of monitoring period, methods used (e.g. cross sections and/or bank pins).

Survey of States and Municipalities within the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

Stream Restoration Crediting Protocols

26. Has your organization used the default rate?

- ◯ Yes, for planning purposes to estimate credits
- ◯ Yes, for calculating credit for constructed projects that did not follow the protocols
- ◯ Yes, for both planning purposes and constructed projects
- ◯ No
- ◯ I don't know

Survey of States and Municipalities within the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

Stream Restoration Crediting Protocols

27. For how many projects has your organization used the default rate? If you don't know, please leave the text box blank and move on to the next question.

Planning Projects

Construction Projects

Survey of States and Municipalities within the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

Stream Restoration Crediting Protocols

28. Has your organization attended any trainings about the stream restoration protocols? Select all that apply.

- ☐ CWP webcast
- ☐ CSN webcast
- ☐ Conference presentation
- ☐ Other (please specify)

29. What would be most beneficial to your organization for using the protocols? Select one.

- ◯ Training workshop
- ◯ List of consultants with demonstrated knowledge of the protocols
- ◯ Don't plan to use the protocols
- ◯ I don't know
- ◯ Other (please specify)

WE&RF Stream Restoration Database

30. Is your organization aware of WE&RF's Stream Restoration Database (USR14)?

- ◯ Yes
- ◯ No
- ◯ I don't know

Survey of States and Municipalities within the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

WE&RF Stream Restoration Database

31. Has your organization contributed any studies to WE&RF's Stream Restoration Database?

- ◯ Yes
- ◯ No
- ◯ I don't know

32. Has your organization ever used WE&RF's Stream Restoration Database to inform your restoration project work?

- ○ Yes
- ○ No
- ○ I don't know

Survey of States and Municipalities within the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

WE&RF Stream Restoration Database

33. Would your organization be willing to contribute to WE&RF's Stream Restoration Database?

- ○ Yes
- ○ No
- ○ I don't know

Survey of States and Municipalities within the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

WE&RF Stream Restoration Database

34. Why wouldn't your organization be willing to contribute to WE&RF's Stream Restoration Database? Select all that apply.

- ☐ No monitoring studies to contribute
- ☐ Data entry is too time consuming/cumbersome
- ☐ Don't believe the database is useful
- ☐ Don't know about the database
- ☐ Other (please specify)

Survey Complete

Thank you for completing the survey. We appreciate your time and interest in helping us with this research project. If you would like to discuss this project or request a copy of the survey results, please contact Lisa Fraley-McNeal – lfm@cwp.org.

APPENDIX B

Outside the Chesapeake Bay Watershed Survey Questions

Survey of States and Municipalities outside the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

The Water Environment & Reuse Foundation (now known as The Water Research Foundation) recently awarded a contract to the Center for Watershed Protection (Center) to survey states and municipalities regarding their use or possible interest in crediting guidance for stream restoration projects developed by WE&RF in 2016, as well as to review monitoring studies in the Chesapeake Bay Watershed that might validate or suggest improvements to the monitoring guidance. The WE&RF Stream Restoration Crediting Guidance includes stream restoration crediting protocols developed for the Chesapeake Bay region and provides a technical framework for quantifying water quality benefits of a specific suite of stream restoration practices. This research project will highlight experiences that utilities and municipalities have had with stream restoration protocols across the Chesapeake Bay watershed, as well as states outside of the Chesapeake Bay watershed that have adopted or are considering adopting stream crediting/trading programs that could benefit from the WE&RF Stream Restoration Crediting Guidance.

We'd like to request that you complete this ten-minute survey about your experience with the WE&RF stream restoration crediting protocols. As a token of our appreciation, everyone who completes the survey will be entered into a drawing for a free Center-sponsored webcast of your choice (a $159 value).

Survey of States and Municipalities outside the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

Organizational Background

1. Name

2. Email Address

3. Phone Number

4. Organization Name

5. State

6. County

7. Is your organization an MS4?

- Yes, Phase I MS4
- Yes, Phase II MS4
- No, not an MS4
- Other (please specify)

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Survey of States and Municipalities outside the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

Stream Restoration Background

8. What is the total number of stream restoration projects your organization has implemented in the past 5 years? Please provide your best estimate.

9. What is the total length of stream restoration projects your organization has implemented in the past 5 years? Please provide your best estimate.

10. What is the total number of stream restoration projects your organization has planned for the next 5 years? Please provide your best estimate.

11. What is the total length of stream restoration projects your organization has planned for the next 5 years? Please provide your best estimate.

12. What type(s) of stream restoration projects does your organization typically implement? Select all that apply.

- [ ] Natural channel design
- [ ] Regenerative stormwater conveyance
- [ ] Legacy sediment removal
- [ ] Floodplain reconnection
- [ ] Channel reconfiguration
- [ ] We don't do stream restoration
- [ ] Other (please specify)

Stream Restoration Background

13. When implementing channel reconfiguration projects, are they done solely as channel reconfiguration or in combination with other project types like natural channel design or floodplain reconnection?

- ○ Solely channel reconfiguration
- ○ Done in conjunction with other project types
- ○ I don't know
- ○ We don't do channel reconfiguration
- ○ Other (please specify)

14. To what degree does your organization typically reconfigure the channel?

- Low (<25% of the total project length reconfigured)
- Medium (25% - 50% of the total project length reconfigured)
- High (>50% of the total project length reconfigured)
- I don't know
- We don't do channel reconfiguration
- Other (please specify)

Stream Restoration Background

15. How does your organization identify locations for your stream restoration projects? Please describe.

16. What is your organization's primary reason for implementing stream restoration projects? Select one.

- Local TMDL requirements
- MS4 permit requirements
- Threats to infrastructure and property loss
- Mitigation purposes
- Other (please specify)

17. How does your organization currently calculate water quality benefits from stream restoration projects?

- ◯ WE&RF Stream Restoration Crediting Guidance
- ◯ MS4 Guidance Document
- ◯ State guidance other than MS4
- ◯ Water quality benefits not calculated
- ◯ I don't know
- ◯ Other (please specify)

Stream Restoration Background

18. What are your organization's primary pollutants of concern when considering water quality benefits? Select all that apply.

- ☐ Nitrogen
- ☐ Phosphorus
- ☐ Sediment
- ☐ Toxics
- ☐ I don't know
- ☐ Other (please specify)

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Survey of States and Municipalities outside the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

Stream Restoration Background

19. Has your state or organization adopted a stream restoration crediting or trading program?

- ◯ Yes
- ◯ No
- ◯ I don't know

Stream Restoration Background

20. Is your state or organization considering adopting a stream restoration crediting or trading program?

- ◯ Yes
- ◯ No
- ◯ I don't know

Survey of States and Municipalities outside the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

Stream Restoration Background

21. Please identify challenges that prevent your state or organization from adopting a stream restoration crediting or trading program. Select all that apply.

- ☐ Limited opportunities for stream restoration
- ☐ Stream restoration is a lower priority compared to other practices
- ☐ Cost
- ☐ Lack of resources
- ☐ Need for clearer/stronger state guidance
- ☐ Lack of credit of stream restoration projects
- ☐ Other (please specify)

Stream Restoration Background

22. Please provide additional details about the crediting or trading program being considered and weblink for the program if available.

Survey of States and Municipalities outside the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

Stream Restoration Background

23. Please provide a short description of your organization’s crediting or trading program and weblink for the program if available.

Survey of States and Municipalities outside the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

Stream Restoration Crediting Guidance

24. Is your organization aware of the Chesapeake Bay Program Stream Restoration Expert Panel recommendations?

- ◯ Yes
- ◯ No
- ◯ I don't know

25. Is your organization aware of the WE&RF's Stream Restoration Crediting Guidance, which includes the CBP Stream Restoration Expert Panel recommendations?

- ○ Yes
- ○ No
- ○ I don't know

Survey of States and Municipalities outside the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

Stream Restoration Crediting Guidance

26. Has your organization used the WE&RF Stream Restoration Crediting Guidance?

- ○ Yes
- ○ No
- ○ I don't know

Survey of States and Municipalities outside the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

Stream Restoration Crediting Guidance

27. Why hasn't your organization used the crediting guidance? Select all that apply.

- ☐ It is too complicated
- ☐ TMDLs focused on pollutants other than nutrients and sediment
- ☐ Unable to collect data needed for protocols
- ☐ Unsure of methodology
- ☐ Unaware of the crediting guidance
- ☐ I don't know
- ☐ Other (please specify)

Stream Restoration Crediting Guidance

28. Is your organization interested in using the WE&RF stream restoration crediting guidance in the future?

- ◯ Yes
- ◯ No
- ◯ I don't know
- ◯ Other (please specify)

Survey of States and Municipalities outside the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

Stream Restoration Crediting Guidance

29. How many projects has your organization used the crediting guidance for? If you don't know, please leave the text box blank and move on to the next question.

Planning Projects

Constructed Projects

30. What is the total length of projects your organization has used the crediting guidance for? If you don't know, please leave the text box blank and move on to the next question.

Planning Projects

Constructed Projects

Survey of States and Municipalities outside the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

Stream Restoration Crediting Guidance

31. What would be most beneficial to your organization for using the WE&RF crediting guidance? Select one.

- ◯ Training workshop
- ◯ List of consultants with demonstrated knowledge of the crediting guidance protocols
- ◯ Don't plan to use the guidance
- ◯ Other (please specify)

WE&RF Stream Restoration Database

32. Is your organization aware of WE&RF's Stream Restoration Database (USR14)?

- ◯ Yes
- ◯ No
- ◯ I don't know

Survey of States and Municipalities outside the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

WE&RF Stream Restoration Database

33. Has your organization contributed any studies to WE&RF’s Stream Restoration Database?

- ◯ Yes
- ◯ No
- ◯ I don't know

34. Has your organization ever used WE&RF's Stream Restoration Database to inform your restoration project work?

- ◯ Yes
- ◯ No
- ◯ I don't know

WE&RF Stream Restoration Database

35. Would your organization be willing to contribute to WE&RF's Stream Restoration Database?

- ◯ Yes
- ◯ No
- ◯ I don't know

Survey of States and Municipalities outside the Chesapeake Bay to Identify Incentives and Impediments to Using the WE&RF Stream Restoration Crediting Guidance

WE&RF Stream Restoration Database

36. Why wouldn't your organization be willing to contribute to WE&RF's Stream Restoration Database? Select all that apply.

- ☐ No monitoring studies to contribute
- ☐ Data entry is too time consuming/cumbersome
- ☐ Don't believe the database is useful
- ☐ Don't know about the database
- ☐ Other (please specify)

Survey Complete

Thank you for completing the survey. We appreciate your time and interest in helping us with this research project. If you would like to discuss this project or request a copy of the survey results, please contact Lisa Fraley-McNeal – lfm@cwp.org.

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