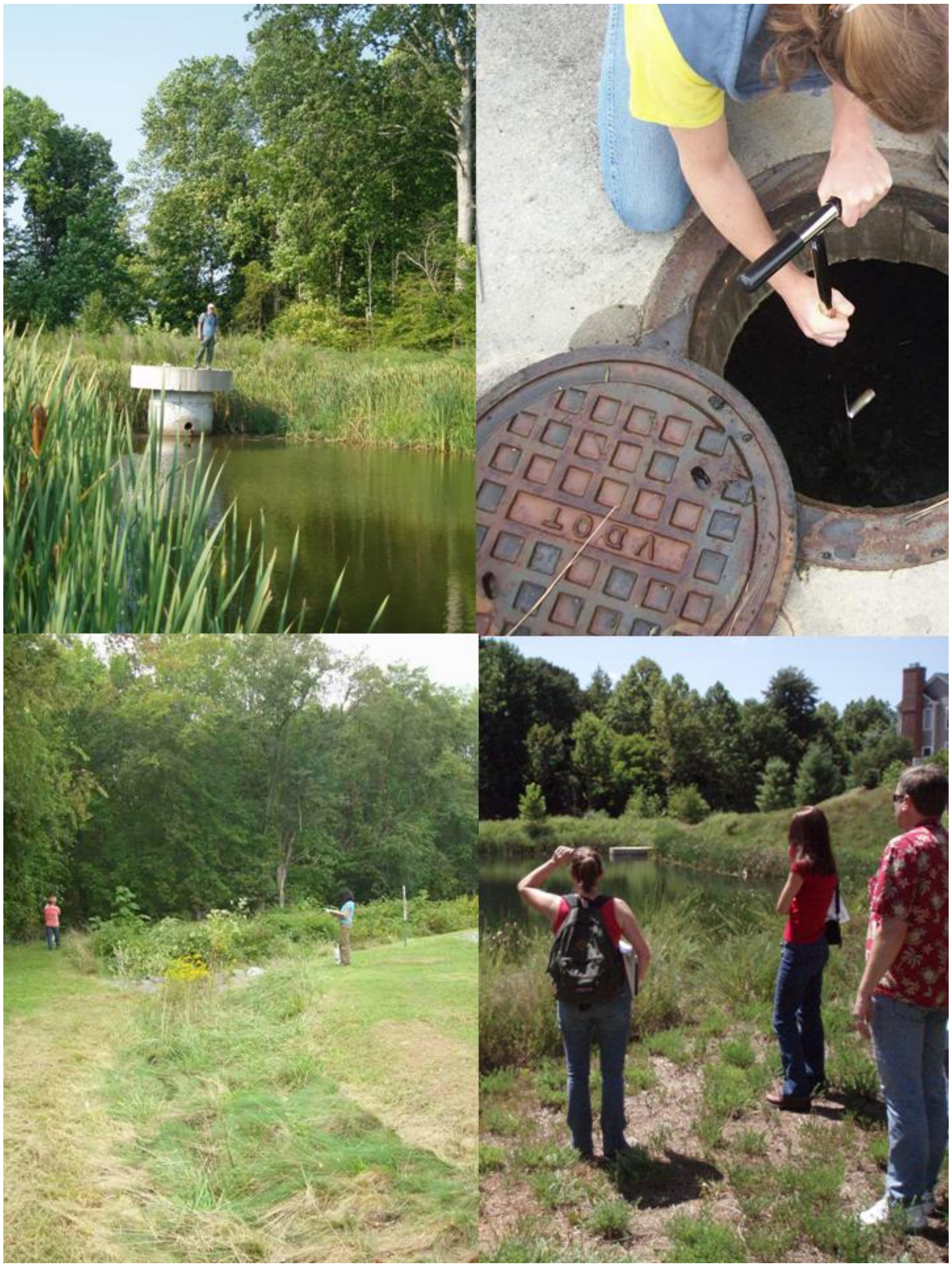
Technical Report

Stormwater BMPs in Virginia's James River Basin:
An Assessment of Field Conditions & Programs

(part of the *Extreme BMP Makeover* project)



June 2009

Final Draft

CENTER FOR WATERSHED PROTECTION

8390 Main Street, 2nd Floor
Ellicott City, MD 21043

PHONE 410.461.8323
FAX 410.461.8324
www.cwp.org
www.stormwatercenter.net

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Prepared by

David Hirschman, Laurel Woodworth, and Sadie Drescher

Center for Watershed Protection, Inc.

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Acknowledgements

The authors would like to acknowledge our *Extreme BMP Makeover* project partners for all their help in gathering BMP data, organizing the survey, and providing field assistance: Jennifer Tribo (Hampton Roads Planning District Commission) and Amber Foster (James River Association). Thank you also to Lisa Fraley-McNeal and Greg Hoffmann from the Center for Watershed Protection, Inc. (CWP) for their review of this report and input on content and format.

Sincere thanks go to the following individuals, municipalities, and organizations for providing effort and insight for this study (for anyone left off the list, please accept our apologies).

City of Chesapeake
City of Newport News
Albemarle County
Derek Bedarf
Repp Glaettli
Greg Harper
Gregor Patsch
Ashley Studholme
Chesterfield County
Weedon Cloe
Scott Flanigan
Scott Williams
City of Hampton
Chuck Fleming
Lisa Wagenbrenner
Henrico County
Cindy Daniels
Brooke Young
Scott Johnson
Pantea Westermann
Keith White
James Uzel
Jeff Perry
James City County
Darryl Cook
Dave Greshamer
Barry Moses
Spotswood Johnson
Scott Thomas
Zuzanna Lesniak
City ofVirginia Beach
Steve McGlaughlin
Clay Bernick
City of Norfolk
Amy Simons
City of Charlottesville
Dan Frisbee
City of Portsmouth
Brendan Bogan
Diane Quick
HRPDC
Jennifer Tribo
Eric Walberg
James River Association
Amber Foster
Michelle Kokolis

The following CWP staff helped to develop and carry out this study:

Alexi Boado
Kelly Collins
David Hirschman
Greg Hoffmann
Lisa Fraley-McNeal
Laurel Woodworth

Funding for the Extreme BMP Makeover is provided by the National Fish and Wildlife Foundation, through Targeted Watershed Grant # 2007-0082-006.

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List of Acronyms and Abbreviations Used in Report

BMP	best management practice
BR	bioretention
CDA	contributing drainage area
CSN	Chesapeake Stormwater Network
CW	constructed wetland
CWP	Center for Watershed Protection, Inc.
DCR	Virginia Department of Conservation & Recreation
DS	dry (water quality) swale
ED	extended detention
EMC	event mean concentration
ESC	erosion and sediment control
ESD	environmental site design
FP	filter practice
GC	grass channel
HOA	Home Owner Association
IC	impervious cover
IN	infiltration
LID	low impact development
LS	level spreader
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
PD	proprietary device
PP	permeable pavement
PW	dry pond, water quality treatment
PU	dry pond, no water quality treatment
UG	underground structure
SA	surface area
TMDL	total maximum daily load
WP	wet pond
WS	wet swale
WQv	water quality volumes

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Section 1. Introduction

In 2008, the Center for Watershed Protection (CWP) and project partners conducted a field survey of nearly two hundred structural stormwater management facilities throughout urban areas of Virginia's James River basin. The following types of stormwater Best Management Practices (BMPs) were included in the survey:

- Bioretention
- Infiltration
- Constructed wetland
- Dry swale
- Grass channel
- Wet pond
- Filtering practice
- Level spreader
- Permeable pavement
- Wet swale
- Dry pond, with water quality treatment volume
- Dry pond, without water quality treatment volume
- Proprietary device
- Underground structure

This survey documented visual indicators of stormwater BMP performance, properly functioning treatment pathways, proper functioning of inlets and outlets, adequate sizing, the integrity of filter media and vegetation, and key maintenance and longevity items. In addition to this field survey, CWP and project partners performed assessments of several local stormwater management programs in the James River Basin. These assessments were intended to help identify programmatic issues that influence BMP performance in a given locality, including plan review procedures, clarity of design standards, BMP inspection programs, and staffing issues.

Both of these activities were conducted as part of CWP's *Extreme BMP Makeover* project, a three-year endeavor to aggressively improve the nutrient reduction achieved by stormwater BMPs within Virginia's James River watershed and the greater Chesapeake Bay region. The *Extreme BMP Makeover* is a partnership between CWP, James River Association, Hampton Roads Planning District Commission, Chesapeake Stormwater Network, and several "Early Adopter" communities within the James River basin (described in Section 2). This project aims to collect the best available information on stormwater BMP design and performance (especially as it pertains to nutrient reductions) and help disseminate those findings to stormwater practitioners throughout the watershed and beyond. In addition to the activities described in this technical report, the partners of this project have, to date:

- Documented research findings on the runoff reduction and nutrient removal capabilities of various stormwater BMPs;
- Developed a "Runoff Reduction Method" framework for compliance with Virginia's updated stormwater management regulations (CWP and CSN, 2008);
- Collaborated with the Virginia Department of Conservation and Recreation and the American Society of Civil Engineers to conduct eleven site design charettes across the state to introduce and test the Method with over four-hundred stormwater practitioners; and
- Produced working drafts of new design specifications for fourteen different stormwater BMPs, emphasizing runoff reduction and enhanced pollutant removal.

This study emerged from a need for empirical data on the relationship between BMP design specifications and BMP performance. BMP design standards have tended to evolve over time, but have also lacked a critical feedback loop based on a systematic review of performance issues in the field. There are many lessons that can be learned from the past three decades of stormwater management in the James River basin – both in its successes and failures. The purpose of this field survey was to attempt to isolate critical stormwater BMP design, construction, and maintenance factors of existing stormwater BMPs, and use this information to improve design guidelines to enhance runoff treatment and longevity of BMPs. This technical report serves to present trends found among the set of BMPs surveyed, as well as BMP problems that are less common, but that should be highlighted to prevent future BMP performance problems.

The timing of this study and the *Extreme BMP Makeover* has been especially opportune because Virginia's Department of Conservation and Recreation is in the process of updating the state's stormwater regulations and BMP design standards. The findings of the BMP survey will help shape the design specifications and maintenance recommendations for the next generation of stormwater BMPs in the Bay region. Furthermore, findings from the local stormwater programs assessment will be used to help local programs identify programmatic issues that influence BMP performance in the field.

Section 2. BMP Field Survey Overview

The BMP field survey took place in selected localities that were identified as “Early Adopters.” These are communities in the James River basin that have a stormwater program and staff dedicated to stormwater and that have expressed interest in participating in the *Extreme BMP Makeover* project. They are also more likely to have employed a wider range of BMPs, including both conventional (e.g., dry ponds and wet ponds) and innovative BMPs (e.g., bioretention cells and infiltration systems). The following eight communities were selected for participation in this field survey (see Figure 1):

- City of Norfolk;
- City of Hampton;
- City of Portsmouth;
- James City County;
- Henrico County;
- Chesterfield County;
- Albemarle County; and
- City of Charlottesville.

Each of these jurisdictions is located within the middle and lower sections of the James River basin. For the purposes of this survey, the study area was roughly divided into three “regions”:

- Coastal Plain (CP) – Norfolk, Hampton, Portsmouth, and James City County (lower reaches near Chesapeake Bay);
- Richmond (RI) – Henrico County; Chesterfield County (middle reaches); and
- Albemarle (AB) – Charlottesville; Albemarle County (upper reaches of study area).

The BMP field survey was conducted during a four-month period in the summer and fall of 2008, with the majority of sites surveyed during the week of August 18 through 22. The field surveys started in the Coastal Plain area and then moved up the James River watershed, working through the Richmond area, and finally into the Albemarle area in central Virginia. Additional field work was conducted over the next several months in the Richmond and Albemarle areas. All field work was completed by October 2008 and resulted in a final survey sample of 187 BMPs. The number of BMPs surveyed is lower than the targeted number of 246 BMPs, due to the following constraints: 1) some BMPs could not be located; 2) some BMPs were under active construction; and 3) some BMPs were not constructed in the designated location.

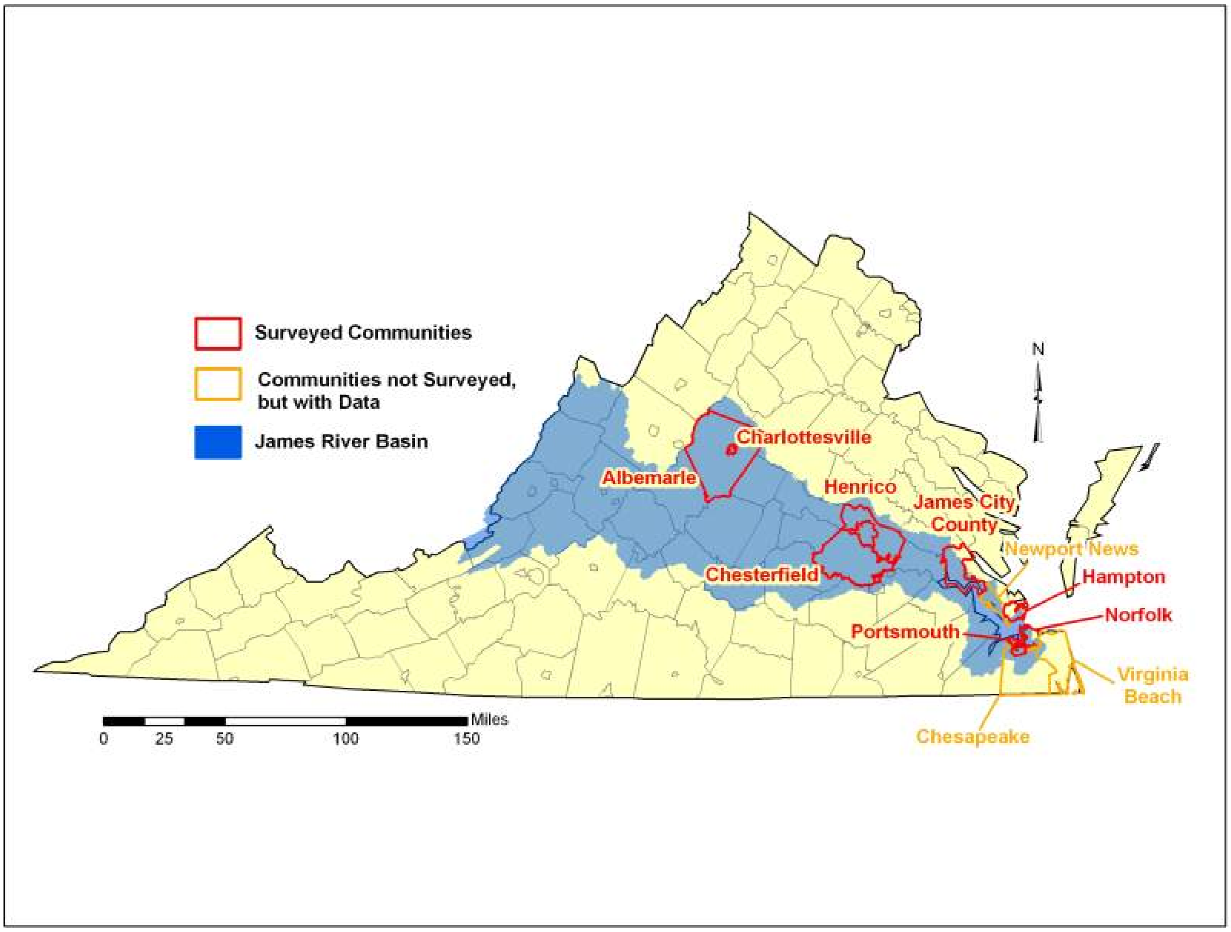


Figure 1. Location of BMP survey areas in James River basin.

Section 2.1. Methodology

Compiling Master List of BMPs

As a first step in the study, CWP staff and partners gathered the most current stormwater BMP inventory databases and geographical information system (GIS) mapping layers from eleven localities in James River basin. In addition to the eight localities identified in the previous section, the cities of Chesapeake, Newport News, and Virginia Beach provided their inventory data. However, for logistical reasons, BMPs were not surveyed in those localities. For most sites, the localities provided data on BMP type, location, year of installation, contributing drainage area, impervious cover within the drainage area, and land use at each site (e.g., commercial, residential, or industrial). In total, CWP gathered a "master database" of over 5,000 stormwater BMPs in the James River basin and mapped each BMP in GIS. This database was used to target BMPs that were distributed across the study area's three "regions." Section 2 describes the database for the 5,000 James River BMPs.

There was a high degree of variability between each locality's BMP GIS data, including variations in data categories, formatting, terminology, variability in data entry, and completeness of data. In order to map the master database of BMPs, each BMP data set needed to have the same categories of data, or "attributes". CWP developed a set of data attribute categories that would be standard across each locality. The GIS data available for each locality were then matched up with the standard set of data attribute categories (see Appendix A) and a master BMP database and corresponding ArcGIS shapefile were created.

Snapshot of Stormwater BMPs in the James River Basin

Among the eleven communities that provided BMP data, there are 5,251 BMPs that have been constructed and entered into local BMP databases and/or GIS-based tracking systems. Table 1 shows the distribution of the various types of BMPs and Figure 2 illustrates the BMPs by community. The table shows that, even in "Early Adopter" communities, "conventional" BMPs, such as wet and dry ponds, still make up the majority of stormwater BMPs (62% of the total). A subset of these ponds was designed originally only for quantity control (approximately 20%), so their performance for water quality treatment can be considered negligible.

Table 1. Types of BMPs used in eleven communities in James River basin.

BMP Type & ID	Number	Percent of Total
Wet Pond (WP)	1785	34%
Dry Pond, no water quality treatment (PU)	933	18%
Dry Pond, water quality treatment (PW)	499	10%
Other (OT)	497	9%
Grass Channel (GC)	439	8%
Infiltration (IN)	428	8%
Bioretention (BR)	237	5%
Proprietary Device (PD)	152	3%
Filtering Practice (FP)	106	2%
Underground Structure (UG)	77	1%
Constructed Wetland (CW)	55	1%
Dry (water quality) Swale (DS)	25	< 1%
Level Spreader (LS)	10	<1%
Permeable Pavement (PP)	6	<1%
Wet Swale (WS)	2	<1%

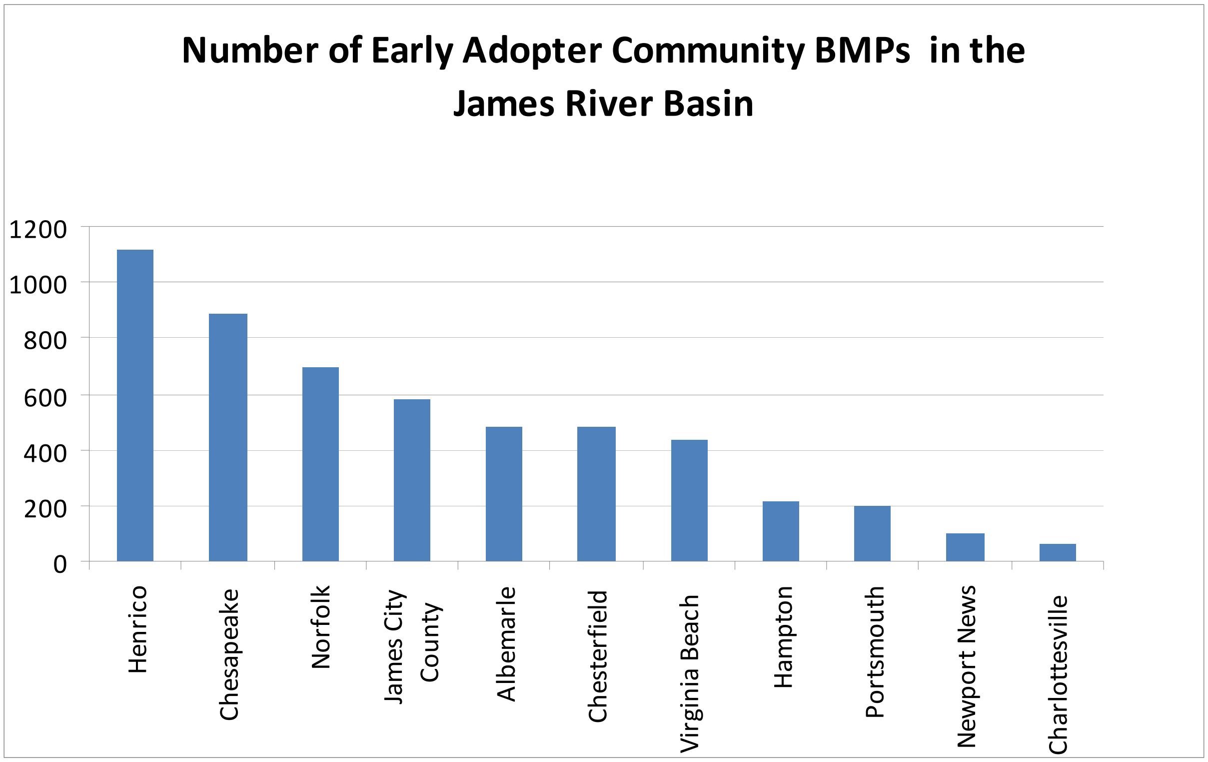


Figure 2. BMPs in the eleven communities in the James River Watershed (assembled from GIS and databases).

Targeted and Randomized Sample Selection

In order to give priority to new and emerging BMP types that are not well represented in published research, but are becoming increasingly popular (e.g., biofiltration and infiltration practices), a target set of BMPs was chosen that is skewed toward these BMP types (i.e., the target BMP sample contained a higher percentage of new and emerging BMPs than their proportion in the overall BMP data set). Table 2 shows the BMP types surveyed and the target distribution of each type in the sample set. Although specific *types* of BMPs were given more preference when forming the sample set, the *individual* BMPs were selected randomly (using a random numbers generator in Microsoft Excel). In some cases, BMPs were replaced with a BMP of the same type if there were logistical hardships to sample the identified site (e.g., excessively long travel distances). More information on the BMP selection process is available in CWP, 2008.

Table 2. BMP types and their targeted proportion of total sample set.	
BMP Type	**% of Sample (original target)**
Bioretention (BR)	20%
Infiltration (IN)	20%
Constructed Wetland (CW)	15%
Dry (water quality) Swale (DS)	10%
Dry Pond, water quality treatment (PW)	7%
Grass Channel (GC)	7%
Wet Pond (WP)	7%
Filtering Practice (FP)	5%
Other (OT)	3%
Level Spreader (LS)	3%
Permeable Pavement (PP)	2%
Wet Swale (WS)	1%
Dry Pond, no water quality treatment (PU)	0%
Proprietary Device (PD)	0%
Underground Structure (UG)	0%

The initial BMP site list was reviewed by stormwater management personnel from each locality in order to cull out any sites that could not be surveyed (e.g., site still under construction; site too far away from other survey sites). There were 246 BMPs identified through this selection process and each BMP was assigned a unique identification code. The localities provided copies of approved stormwater design plans or as-built plans for approximately 40% of the BMPs surveyed. Whenever possible, the survey teams used these plans during field surveys to compare the design specifications to the observed BMP conditions. The purpose of this analysis was to determine if observed BMP performance issues resulted from problems during the construction phase rather than from problems with the original design.

BMP Field Evaluation Form

To conduct this field-based visual assessment of stormwater BMP performance, CWP created a four-page *BMP Evaluation Form* that can be used for a wide variety of stormwater BMP types (see Appendix B). The project team reviewed several survey instruments from past stormwater BMP field studies (Galli, 1992; Hirschman et al., 2008; Law et al., 2008; Schueler et al., 2007) and synthesized a draft evaluation form. CWP staff field tested various drafts at several different types of BMPs near Ellicott City, MD and Charlottesville, VA. Finally, these draft evaluations were vetted by staff from the “Early Adopter” communities. Based on the literature review, field evaluations, and “Early Adopter” staff input, the final field survey protocol and field form (BMP Evaluation Form) were developed. The field form was then digitized into a format compatible with the Trimble handheld PCs containing portable GIS technology that were used in the field survey. The BMP Evaluation Form included the fields listed in Table 3 along with a drawing sketch area:

Table 3. Data collected on the BMP Evaluation Form (field form) for the study.	
BMP type, age, location, and ownership	Inlet type, size, and condition
Contributing drainage area (CDA)	Pretreatment type and functionality
Percent impervious cover & land use in CDA	Other BMP features
Designed water quality volume (WQv)	Conveyance system
BMP dimensions & observed WQv	Vegetation type & quantity
Design storm	General problems
Signage	Water quality issues (color, odor, and turbidity)
Outlet type, size, and features	Severity of trash, bank erosion, etc.
Outlet conditions (erosion, clogging, and structural)	Good and poor design features
Downstream conditions	Design plan verification
Filter media characteristics	Overall performance score

In the "general problems" category, the field form identified a variety of performance and maintenance issues, including:

- General maintenance needed, lack of access for maintenance;
- By-passing of inlets and/or outlets;
- Incorrect flow path;
- Short-circuiting of treatment mechanism;
- Erosion at embankments or within facility;
- Clogged media or underdrains;
- Inappropriate media material;
- Inappropriate soil for infiltration designs;
- Poor vegetation quality;
- Failing structural components; and
- Safety issues.

In addition, field teams noted on the field form an "Overall Performance Score" for each BMP, based on the following scale:

- Excellent design and function, no general problems with performance (score of 8 – 10);
- BMP is well designed, but is undersized or has a few performance problems (6 – 7);
- BMP is adequately designed, several problems with performance are noted (3 – 5); and
- Poor BMP design, severe performance problems or failure (1 – 2).

Field Team Training and Calibration

In addition to CWP staff and project partners, stormwater management staff from each of the participating Early Adopter communities also participated in the field component of the project. To ensure that all survey participants understood how to use the BMP Evaluation Form and how to remain consistent with each BMP assessment, a field manual was provided for all participants to review before the survey date. CWP staff calibrated their assessment process by completing an evaluation form together as a group prior to the survey. All non-CWP participants were given training in the field at the time of the survey, but were also accompanied by a CWP team leader during the entire survey. These measures were used in order to provide consistency between the survey teams. For the majority of sites, evaluation forms were filled out both on paper and electronically (with Trimble handheld PC units containing portable GIS technology) to simplify the process of data entry and to provide a data back-up.

Data Processing, Quality Control, and Analysis

Upon completion of the survey, each CWP survey team leader reviewed their field forms for incomplete information and entry errors and compiled photos from each site. CWP staff either downloaded data from the Trimble handheld PCs or entered it manually to the Microsoft Excel spreadsheet database, depending on whether data was collected electronically or on paper. In order to improve the BMP Evaluation Form for future surveys, a comprehensive review for the form's content and layout was conducted by CWP staff.

CWP staff then analyzed the field survey data. As a first step in recording apparent trends in BMP design and function, all CWP field staff compiled anecdotal field observations and incorporated site photos to illustrate these observations. Using these initial trends and general observations, an initial framework was developed to statistically analyze the survey data and identify *actual* trends in BMP design, construction, and maintenance issues. Data analysis was performed through standard statistical methods in Microsoft Excel, including mean, median, quartiles, standard deviation, etc. The following sections of this technical report detail the results of these analyses, describe the implications for overall BMP performance, and highlight opportunities for BMP improvement.

Section 2.2. Overview of the Surveyed BMP Population

BMP Types Surveyed

As described in Section 2.1 above, new and emerging BMP types were prioritized before the field survey. In Table 4, the number of BMPs surveyed of each BMP type is compared to the original targeted number of each BMP type. The only BMP types that differed more than 3% from the original targeted proportions were wet ponds, which were surveyed more than intended and dry swales, which were surveyed less than intended. All other BMP types were within 3% of the original sample distribution goal.

Table 4. BMP survey sample compared to targeted survey sample.					
BMP Type	**Target (#)**	**Target (%)**	**Surveyed (#)**	**Surveyed (%)**	**Difference (%)**
Bioretention (BR)	50	20%	40	21%	1%
Infiltration (IN)	50	20%	33	18%	-2%
Wet Pond (WP)	18	7%	23	12%	5%
Constructed Wetland (CW)	35	14%	22	12%	-2%
Dry Pond, water quality treatment, (PW)	18	7%	18	10%	3%
Grass Channel (GC)	18	7%	12	6%	-1%
Filtering Practice (FP)	13	5%	10	5%	0%
Dry Swale (DS)	25	10%	9	5%	-5%
Permeable Pavement (PP)	6	2%	6	3%	1%
Dry Pond, no water quality treatment (PU)	0	0%	5	3%	3%
Level Spreader (LS)	10	4%	4	2%	-2%
Proprietary Device (PD)	0	0%	2	1%	1%
Other (OT)	8	3%	2	1%	-2%
Wet Swale (WS)	2	1%	1	1%	0%
TOTAL	**253**		**187**		

BMPs Surveyed by Region

Figure 3 shows the distribution of surveyed BMPs among the three regions of the study area in the James River basin.

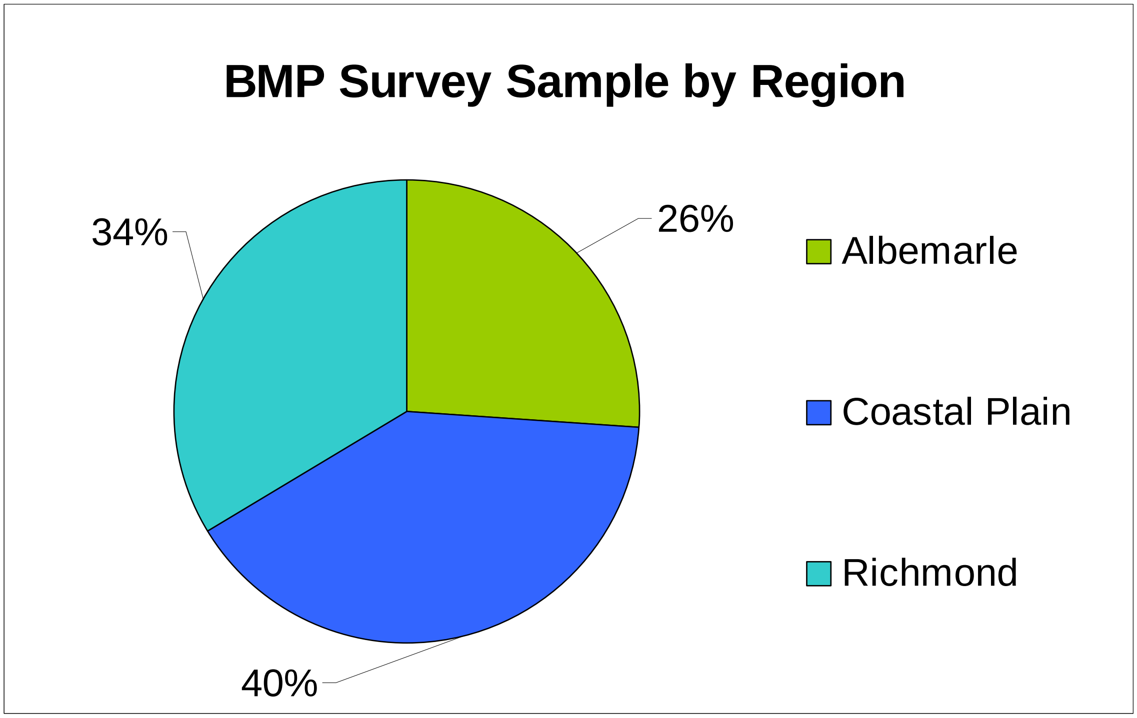


Figure 3. Field surveyed BMPs by region.

BMPs Surveyed by Land Use

As part of the field survey, each BMP was characterized by the land uses within the contributing drainage area (CDA). Figure 4 depicts the percentage of BMPs that had a particular type of land use within its CDA. The four most common land uses in the sample set included:

- Commercial (e.g., retail, office, garages, and warehouses) -- 36% of surveyed BMPs had commercial land uses in the CDA;
- Institutional (e.g., churches, schools, government buildings) -- 26% of BMPs;
- Residential (Suburban) -- 16% of BMPs; and
- Industrial -- 11% of BMPs.

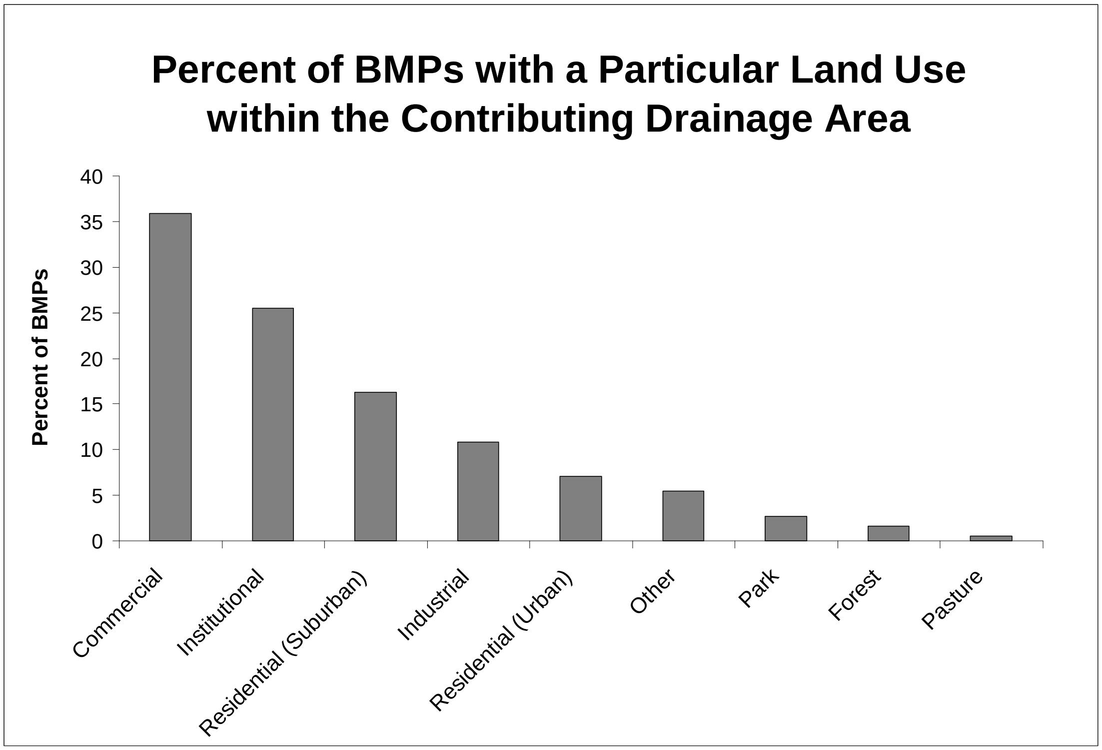


Figure 4. Percent of BMPs with a particular land use within the CDA. For instance, 36% of surveyed BMPs had at least some commercial land use within the CDA. Some BMPs had multiple land use types within the CDA, so the percentages do not add up to 100%.

Contributing Drainage Area of BMPs Surveyed

Seventy-eight percent of the surveyed sites had data available on the contributing drainage area (CDA) to the BMP, derived from local government databases (44%), field measurements (30%), and design plans (26%). Table 5 shows the mean CDA by type of BMP. It is not surprising that wet ponds had the largest mean CDA and that grass channels and infiltration had the smallest.

Table 5. Mean contributing drainage area by BMP type.

BMP Type	Mean Contributing Drainage Area (ac)	Standard Deviation
Wet Pond (n=18)	65.0	146.0
Constructed Wetland (n=18)	13.0	26.0
Wet Swale (n=1)	8.0	N/A
Level Spreader (n=5)	5.1	1.9
Pond, Water Quality Detention (n=15)	4.4	6.1
Dry Swale (n=9)	3.6	7.3
Bioretention (n=26)	3.8	13
Infiltration (n=28)	1.3	1.7
Grass Channel (n=10)	0.6	0.6

Section 2.3. General Findings for All BMP Types

Overall Performance Scores

As noted in Section 2.1, the field teams assigned an overall performance score to each BMP to indicate general design, function, and performance issues. Figure 5 shows the range of overall performance scores for each type of BMP in the "box and whisker" plot. As can be seen in the figure, most types of BMPs had mean scores in the range where the BMP design is adequate (overall performance score ≥ 6), but there are several performance problems. Wet ponds, dry ponds, infiltration, and grass channels had somewhat lower mean scores and level spreaders generally had severe performance issues.

As might be expected, the range of performance scores is large, as each type of practice has representatives that are failing or performing very well. Some of the practices with the widest performance score ranges include bioretention, grass channels, infiltration, permeable pavement, and wet ponds. This may indicate that design, installation, and maintenance guidelines for these practices are not well articulated or applied consistently.

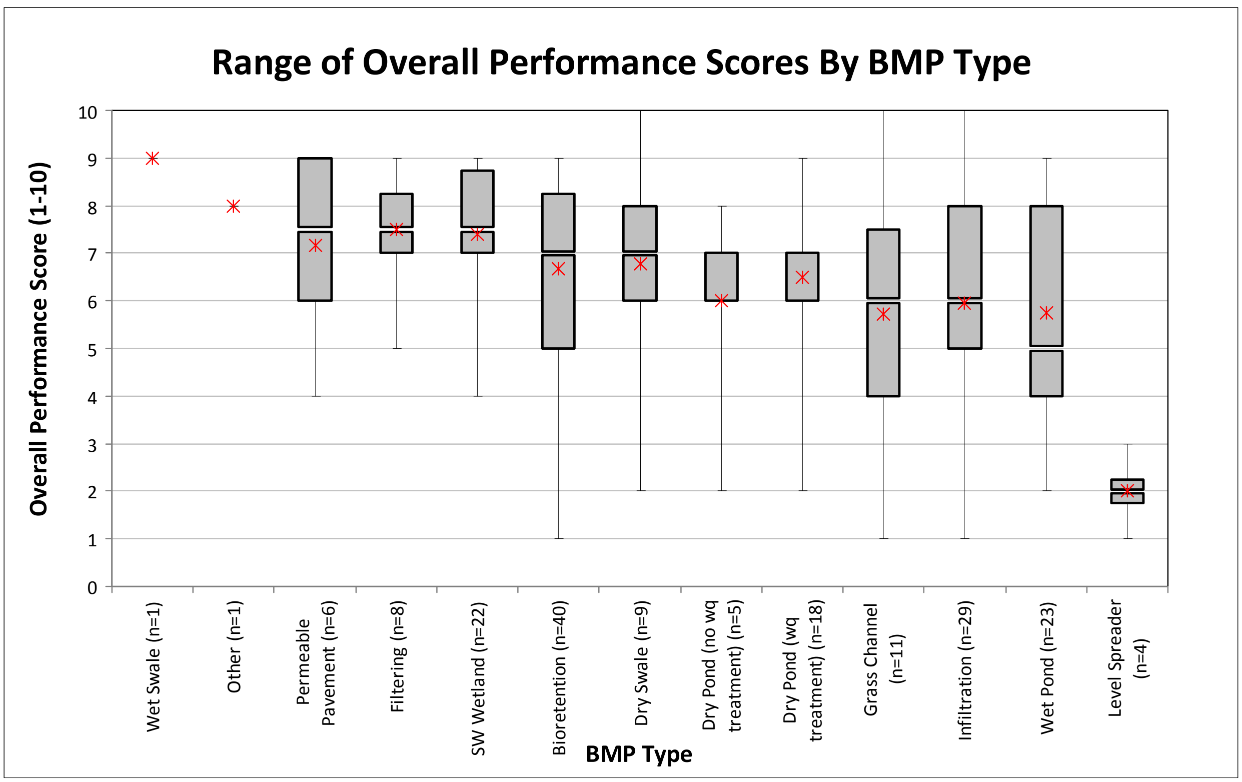


Figure 5. Box and whisker plot for the range of overall performance scores by BMP type. For each BMP, the plot shows the entire range of data (thin line), the 25th and 75th percentile values (bottom and top of box), the median (horizontal line across box) and mean (star shape). For some types of BMPs (Wet Swale and "Other") the data set was too small to support a box and whisker plot.

General Performance Problems

Specific BMP performance issues identified by the field survey are summarized below:

- <u>Ineffective Treatment:</u> In many BMPs, the treatment mechanism is not effective due to short-circuiting (e.g., short flow path from inlet to outlet) (15%), no pretreatment (28%), ineffective treatment mechanism (such as missing media layers or treatment components) (11%), incorrect flow paths (7%), and/or water by-passing inlets (7%).

- <u>Vegetation:</u> Vegetation management is often an issue with BMPs because the target vegetative community is not known or understood. These management issues can include excessive vegetation and invasive species (17%), trees on embankments (11%), or inadequate vegetation (10%).

- <u>Erosion and Deposition:</u> Some BMPs were not stable due to embankment erosion (14%), erosion within the facility itself (7%), or sediment deposition within the facility (24%).

- <u>BMP Maintenance and Owner Awareness:</u> Overall, 46% of BMPs were in need of some type of maintenance and 14% had no maintenance access to the BMP. In some cases, field conditions suggested that property owners were unaware of the BMP or its purpose and functions.

The performance issues that were identified most often are shown in Figure 6.

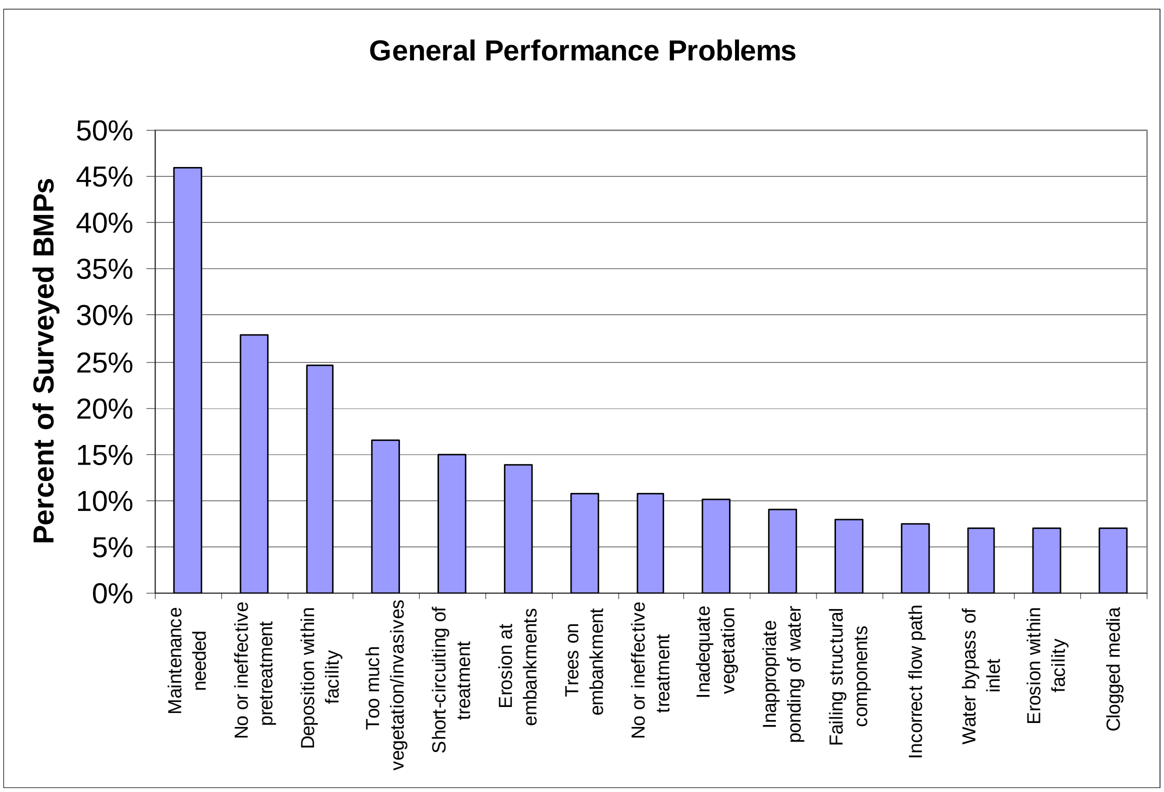


Figure 6. Percent of surveyed BMP general performance problems.

Section 3. Design Issues

A major BMP field survey objective was to identify key BMP design issues that affect performance. This section highlights survey results in the following design categories:

- BMP geometry (pathway of water through the BMP);
- Pretreatment;
- Filter media; and
- Other design issues.

Section 3.1. BMP Geometry

The internal geometry of BMPs is one of the most important design objectives that affect performance (Schueler, et al., 2007; Claytor, 2003). BMP geometry includes the flow path, the relationship of inlets to outlets, and other factors that influence the residence time of runoff within the BMP.

The field survey investigated several aspects of BMP geometry, including the length-to-width ratio (length/width), the shortest flow path from inlet to outlet, and general flow path observations (see Figure 7).

Length to Width Ratio

Figure 8 is a box and whisker plot illustrating the length/width data for BMPs for which the data were available. As would be expected, linear BMPs (dry swales and grass channels) had the highest median length/width ratios. Wet ponds, dry ponds, and bioretention had a wide range of length/width values, with stormwater wetlands having less variability. All of these practices had median length/width values in the 2:1 to 3:1 range.

Table 6 shows the length/width values for wet ponds, dry ponds, stormwater wetlands, and bioretention and compares the field study values with the length/width design guidelines from Virginia's existing Stormwater Management Handbook and the proposed draft specifications produced by the Chesapeake Stormwater Network. The table also shows the length/width values for BMPs that had an overall performance score greater than 6 (generally, BMPs that were deemed to be performing well). These "higher performing" BMPs generally have equivalent or higher median length/width values than the overall data set (with the exception of dry ponds). These data suggest that length/width guidelines for these practices should be increased in a number of cases, as specified in the table.

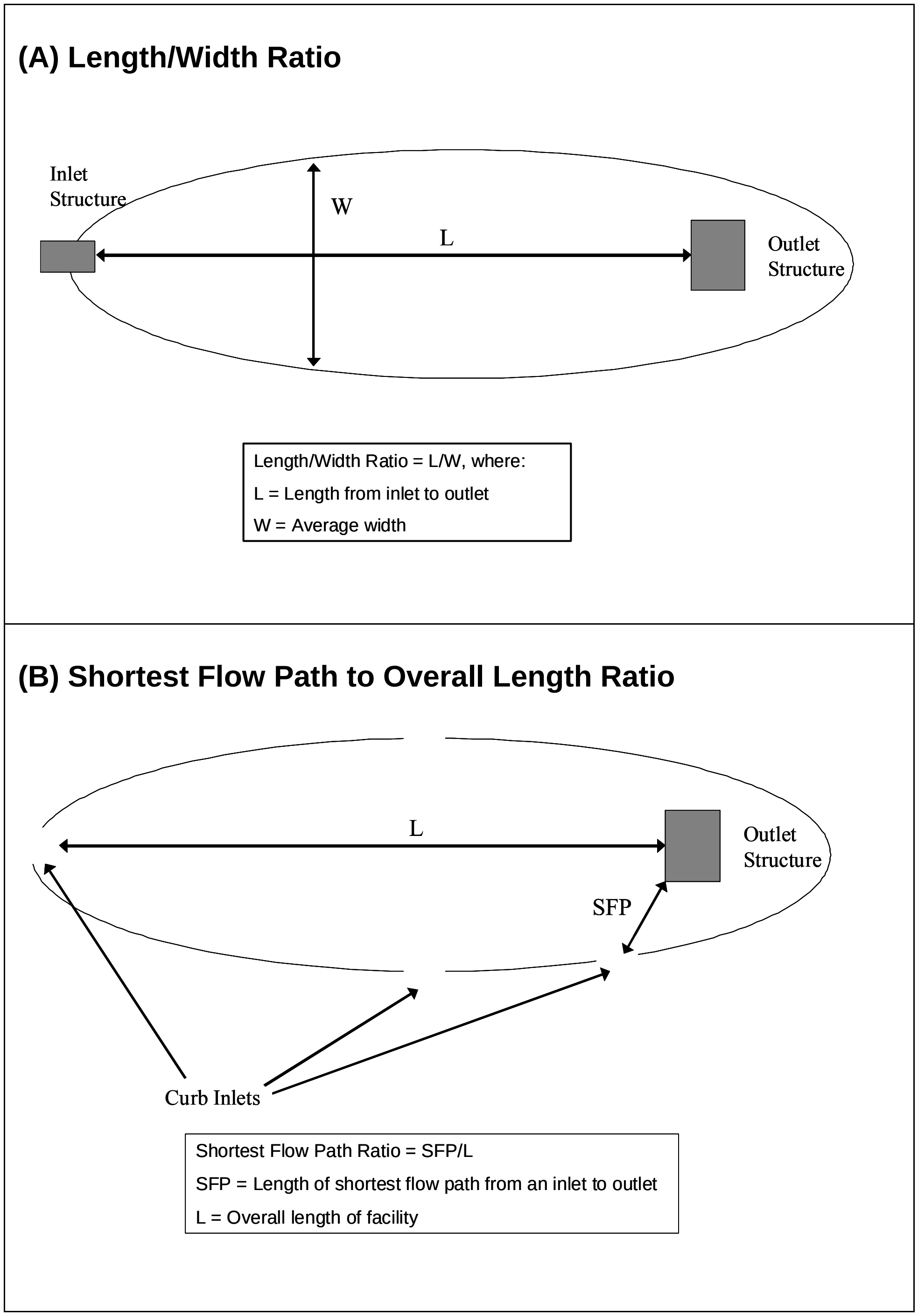


Figure 7. Illustrations of general concepts of BMP geometry: (A) length/width ratio and (B) shortest flow path.

Table 6. Length/Width ratio data for selected BMPs.						
Type	**Min/ Max**	**Median**	**Median for Scores > 6**	**Existing Standard (Blue Book)[1]**	**Proposed Standard (Draft Specifications)[2]**	**Recommended Value[3]**
Wet Pond	0.5/52.5	2.3	3.5	2.0 (multi-cell)	Level 1 = 1.0 Level 2 = 1.5 (multi-cell)	Level 1 = 2.0 Level 2 = 3.0 (multi-cell)
Dry Pond	1.3/29.0	3.0	2.7	2.0 (ED basin)	Level 1 = 1.0 (forebay, micropool) Level 2 = 1.5 (additional cells)	Level 1 = 2.0 Level 2 = 3.0 (additional cells)
Wetland	0.7/8.5	2.0	2.0	1.0 (wet weather) 2.0 (dry weather)	Level 1 = 1.0 (forebay) Level 2 = 1.5 (multiple cells)	Level 1 = 2.0 (forebay) Level 2 = 3.0 (multiple cells)
Bio-retention	0/111.7	2.9	3.5	Recommended minimum width = 10 feet, length = 5 feet (specific L/W ratio not addressed)	Level 1 = one cell Level 2 = 2 cells (specific L/W ratio not addressed)	Level 1 = 3.0 Level 2 = 3.5 (2 cells)

[1] Virginia Stormwater Management Handbook, Volume 1, 1999.
[2] Chesapeake Stormwater Network, Bay-Wide Design Specifications, http://www.chesapeakestormwater.net/. Level 1 designs represent a standard BMP design, and Level 2 includes design enhancements to boost nutrient removal performance.
[3] For some sites, these values may be difficult to obtain through simple BMP dimensions. In these cases, it would be appropriate for the standards to specify design features that lengthen the flow path to the required ratio, including baffles and/or multiple cells.

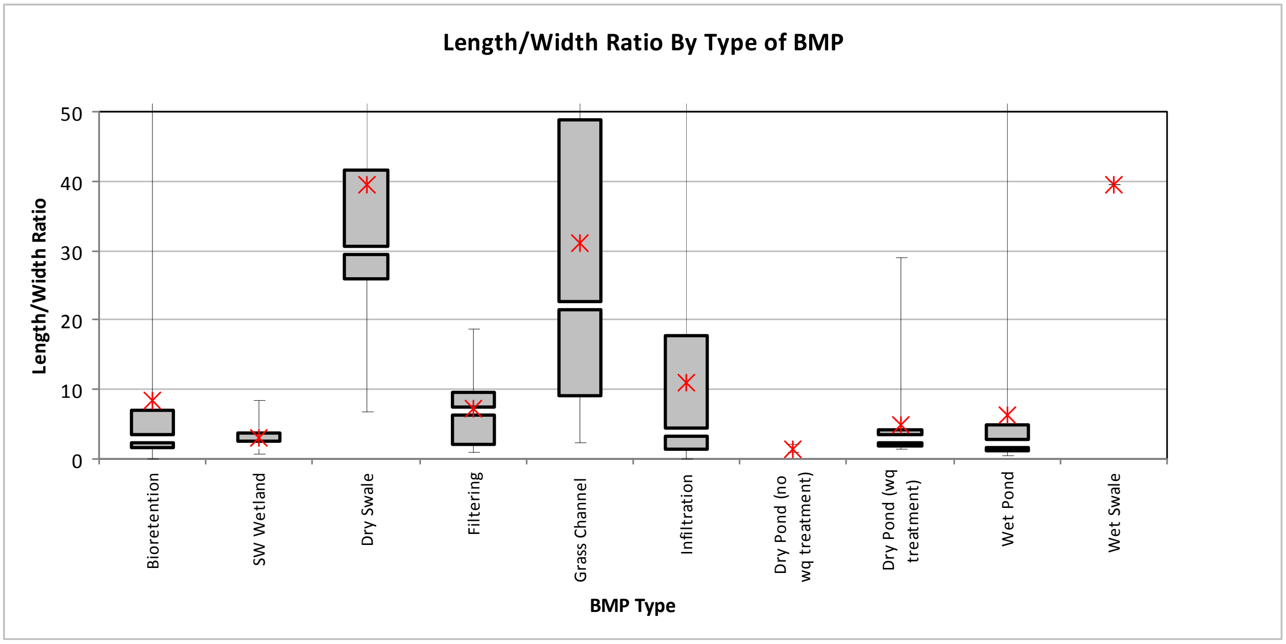


Figure 8. Length to width ratio box and whisker plot. Note: scale adjusted for graphical display; some maximum points are off the scale and not shown in this figure.

Shortest Flow Path

Figure 9 shows the ratio of the shortest flow path to the overall length for bioretention, stormwater wetlands, dry ponds, and wet ponds. The shortest flow path is the distance from the inlet to the outlet for the inlet that is closest to the outlet (see Figure 7). This is most relevant for BMPs that have multiple inlets. This measurement is important because, while a BMP may have a good overall length and/or good length to width ratio, some of the drainage area may be receiving inadequate treatment because most of the BMP's area or treatment mechanism could be by-passed. Median values for the ratio of shortest flow path to overall length range from 0.3 for bioretention to 0.7 for stormwater wetlands. There is a lot of variability in these data because some BMPs had a ratio of 1.0 (for instance, if there was only one inlet at the top of the BMP). Table 6 shows these data in tabular format and includes the values for BMPs with overall performance scores > 6. In this case, the values for high performing BMPs were not substantially different than values for the overall data set.

The shortest flow path ratio is not usually included as a BMP design specification. However, given the large number of BMPs with poor or short-circuited flow paths observed in this study, it is recommended that this become a design objective. The specifications need specific qualifiers and thresholds, such as at least 80% of the CDA must meet the shortest flow path guideline (in some cases, an inlet relatively close to the outlet may be unavoidable due to site drainage, topography, and storm sewer design – however, these inlets should represent only a small part of the drainage area). Recommended values for the shortest flow path ratio are provided in Table 7. Figure 10 illustrates poor and good examples for BMP geometry and includes photographs from the field survey.

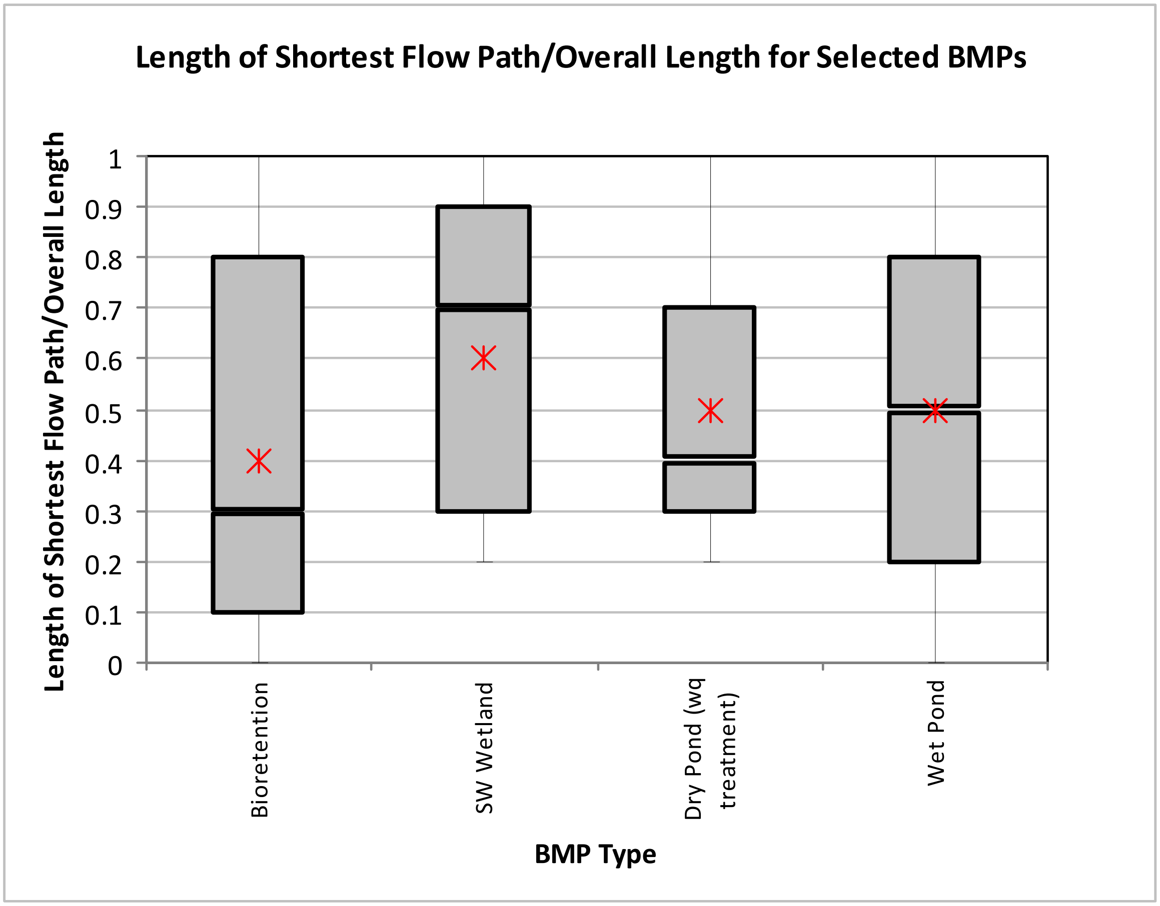


Figure 9. Ratio of shortest flow path to overall length for bioretention, stormwater wetlands, dry ponds, and wet ponds.

Table 7. Length of shortest flow path to overall length for selected BMPs.

Type	Min/Max	Median	Median for Scores > 6	Recommended Value[1]
Wet Pond	0.0/1.0	0.5	0.7	Level 1 = 0.5 Level 2 = 0.8
Dry Pond	0.2/1.0	0.4	0.4	Level 1 = 0.4 Level 2 = 0.7
SW Wetland	0.2/1.0	0.7	0.7	Level 1 = 0.5 Level 2 = 0.8
Bioretention	0.0/1.0	0.3	0.25	Level 1 = 0.3 Level 2 = 0.8

[1] It is assumed that some qualifiers may apply; for instance, the standard could be that at least 80% of the CDA meets the shortest flow path ratio. Level 1 designs represent a standard BMP design, and Level 2 includes design enhancements to boost nutrient removal performance.

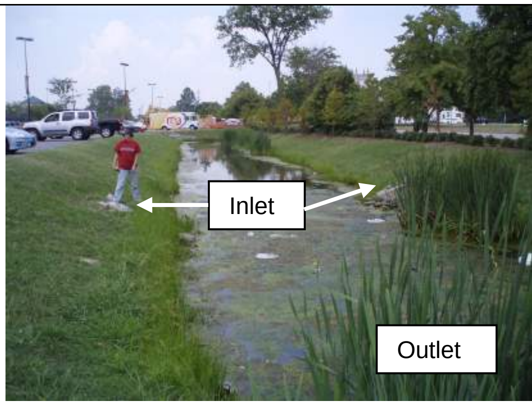
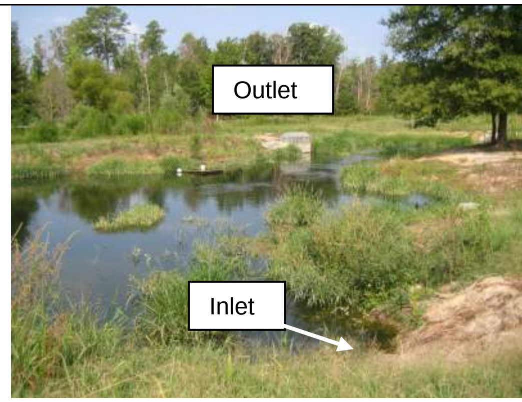
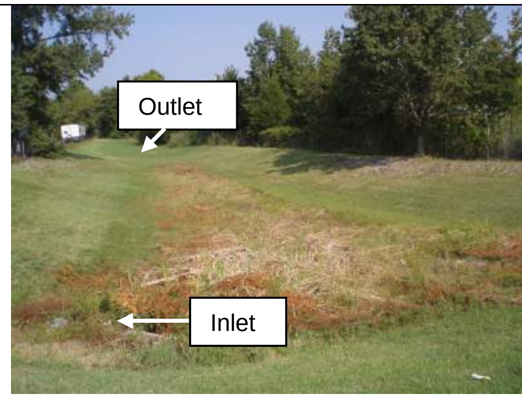
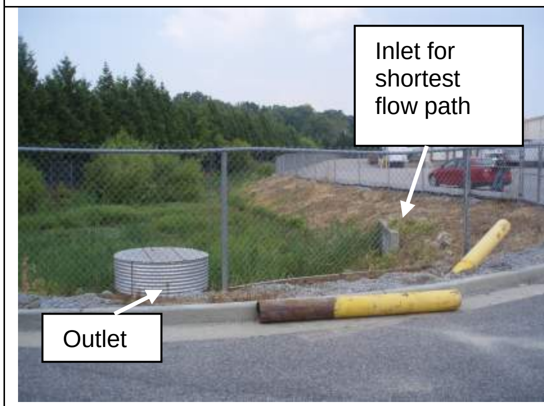
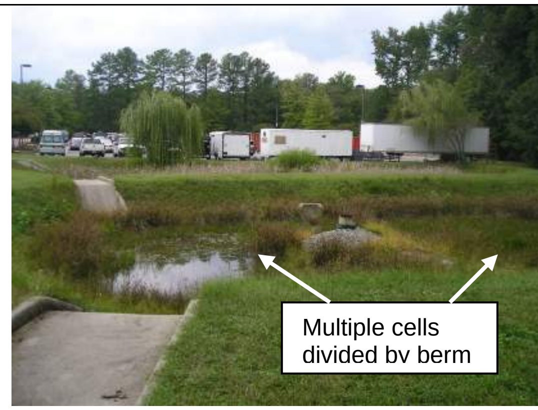
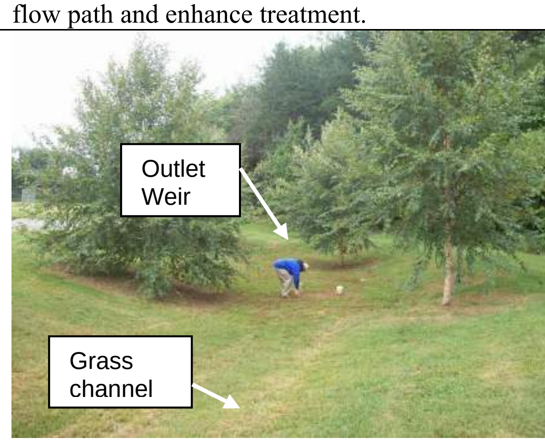
Poor Examples	Good Examples
 Very long wet pond with very short flow path; shortest flow path is 25 feet out a total pond length of 315 feet.	 Wet pond with a good length/width ratio of 3.4:1
 Dry pond with curb cuts very close to outlet, bypassing treatment mechanism.	 Dry pond with L/W ratio of 8.9 and a long flow path.

Figure 10. Photos illustrating poor and good BMP geometry.

<table>
<tr><th>Poor Examples</th><th>Good Examples</th></tr>
<tr><td>

Stormwater pond/wetland – shortest flow path is 25’ out of a total length of 1000’.</td><td>

Stormwater wetland with multiple cells to lengthen flow path and enhance treatment.</td></tr>
<tr><td>

Good bioretention area, but the last curb cut is very close to the outlet. This issue may be hard to resolve for curb cut designs.</td><td>

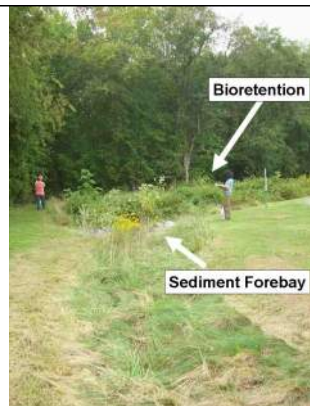
Bioretention with long flow path – entry channel is grass swale, which provides pretreatment.</td></tr>
</table>

Figure 10 (continued). Photos illustrating poor and good BMP geometry.

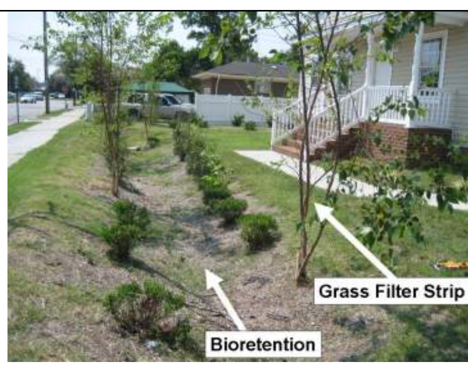
Section 3.2. Pretreatment Measures

Using pretreatment can be an effective design feature to reduce heavy particles, debris, and trash entering the BMP. Figure 11 shows the variety of pretreatment types used in the James River basin. The pretreatment types identified on the field form included:

- Sediment forebay;
- Grass channel;
- Riprap channel or apron;
- Gravel filter strip;
- Grass filter strip;
- Plunge pool;
- Stone diaphragm; and
- Other.

<table>
<tr><th>Pretreatment Type</th><th>Field Examples</th></tr>
<tr><td>Riprap Channel or Apron</td><td> </td></tr>
<tr><td>Sediment Forebay</td><td>


</td></tr>
<tr><td>Grassed Channel</td><td>


</td></tr>
<tr><td>Grass Filter Strip</td><td>

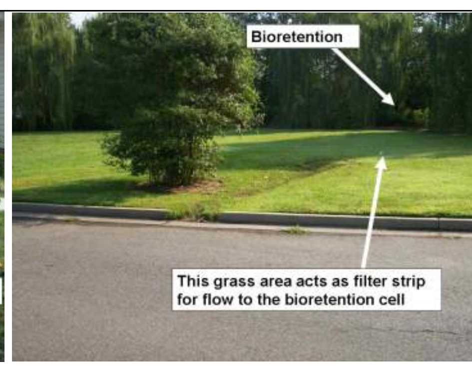

</td></tr>
</table>

Figure 11. A variety of pretreatment measures used in the James River basin.

Pretreatment measures were found at 43% of the sites. As shown in Figure 12, the most common pretreatment measures identified were riprap channels or aprons (38% of sites with pretreatment) and sediment forebays (24% of sites with pretreatment). In addition, survey teams observed several sites that used more than one type of pretreatment. Several BMPs also used additional pretreatment practices, such as manufactured devices (filters and hydrodynamic), settling vaults, and flow dissipaters. Section 5 (Maintenance Issues) provides additional data on the performance and maintenance issues with pretreatment. Bioretention BMPs had a higher occurrence of riprap channel or apron for pretreatment and wet ponds had a higher occurrence of sediment forebay pretreatment (Figure 13).

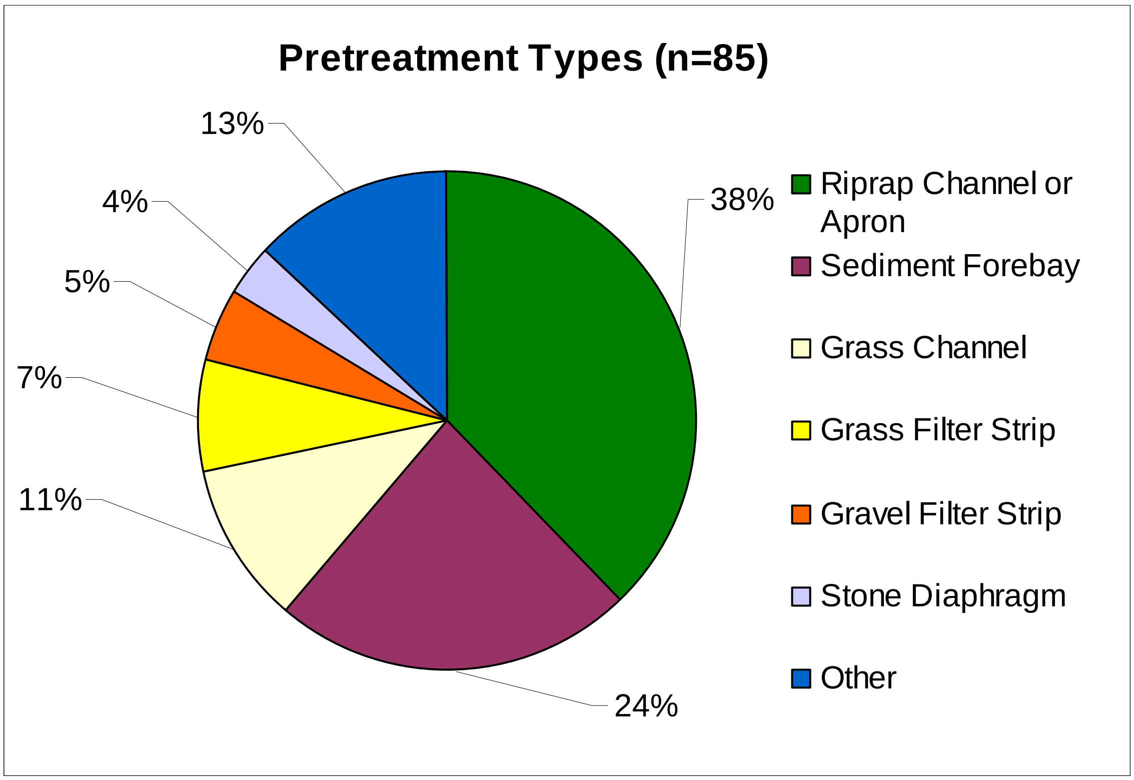


Figure 12. Riprap channel or apron and sediment forebay were the most common pretreatment types observed in the field. This data represents the pretreatment type (%) for sites with pretreatment. Note that several sites had more than one pretreatment type.

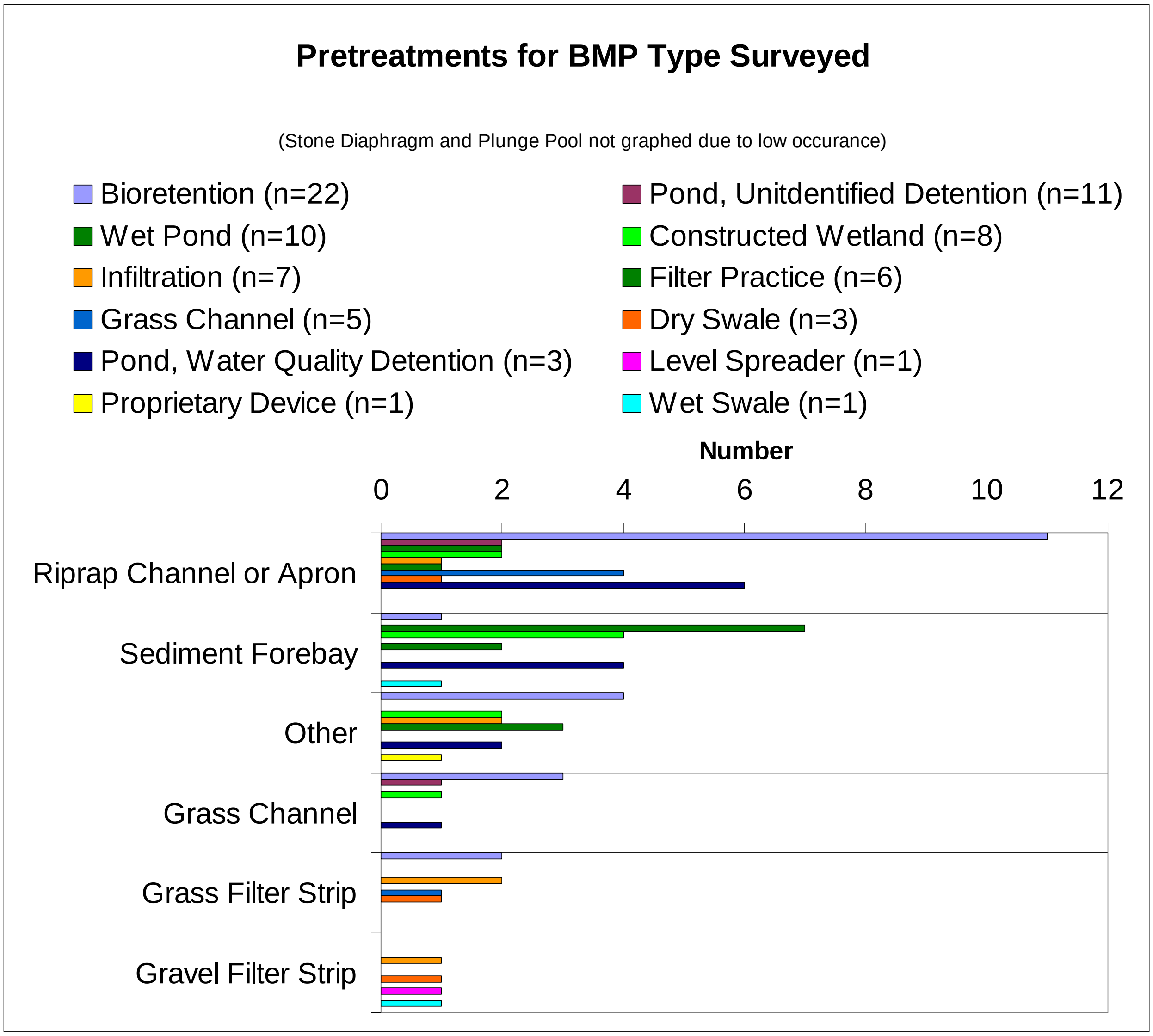


Figure 13. Pretreatments for the BMP type surveyed.

Section 3.3. Filter Media

Trends in filter media type were identified for several different types of BMPs. The predominant media type for infiltration BMPs is gravel (Figure 14), although it is important to note that one third of infiltration trenches and basins contained several media types within the facility (e.g., sand with stone sub-base). Filter practices, usually located underground, primarily use sand as the filter media. Permeable pavements vary between gravel, sand, and other types of filter media.

Almost all bioretention cells and dry swales contain soil media, with sand as the dominant soil component. The average depth of soil media in bioretention cells and dry swales was 27 and 20 inches, respectively. For the sake of comparison, these values were compared with proposed Bay-wide specifications proposed by the Chesapeake Stormwater Network (CSN, 2009). These draft specifications include design variations for Level 1 and 2 designs. Level 1 represents a standard BMP design, and Level 2 includes design enhancements to boost nutrient removal performance. For bioretention, the draft specifications include media depths of 24 inches for Level 1 and 30 inches for Level 2. For dry swales, these standards are 18 and 24 inches. Therefore, the average values found in the field are comparable to the proposed standards.

Performance issues related to these types of filter media are discussed in Section 4 (Construction Issues).

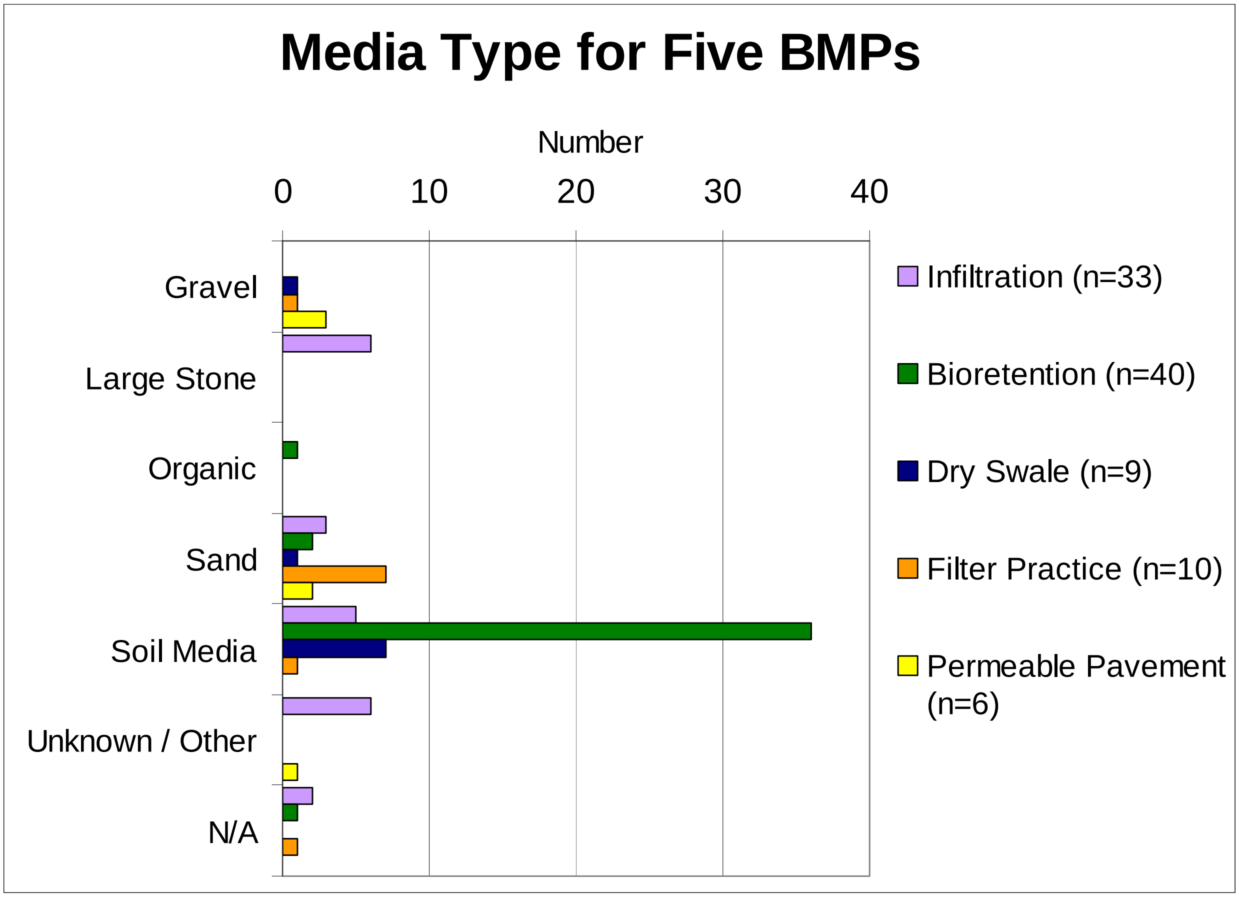


Figure 14. Number of BMPs with each media type for five BMP types.

Section 3.4. Other Design Issues

A number of good and poor design features were observed among the surveyed BMPs that have not been discussed up to this point. In the field, survey teams descriptively characterized BMP features and conditions that were generally positive or negative (anecdotal information). The top five “Good Design Features” and “Poor Design Features” that were noted most frequently are shown in Table 8.

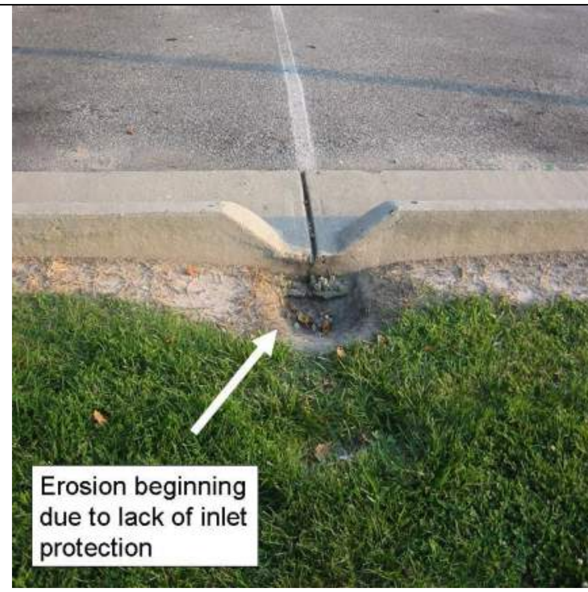
By far, the most frequent observation noted in the field for site “Good Design Features” was that the stormwater BMP had *plenty of vegetation cover*, which can contribute to ideal conditions for pollutant uptake by plants and pollutant breakdown by soil microorganisms (Davis et al., 1998; Hunt, 2007; Lenhart, 2008). Forty sites where called out as having good coverage of vegetation within the BMP. Take note that this relates specifically to quantity and not necessarily to plant diversity.

Table 8. Top five "good" and "poor" design features.	
Good Features	**Sites that noted feature**
Plenty of vegetation cover	40
Good soil / infiltration media	16
Collecting runoff from large contributing drainage	15
Well integrated into site	13
Aesthetically pleasing	12
Poor Features	**Sites that noted feature**
Lack of detention volume	21
Difficult to maintain	15
Improper elevations (inlet, outlet, berms, etc.)	14
Monoculture vegetation	10
Only treating small portion of site	10

The most frequently noted "Poor Design Feature" was a *lack of detention volume*, often due to an outlet that was placed too low, therefore decreasing the depth of water that can be stored in the BMP. This design problem is also reflected in those BMPs whose observed water quality volume storage capacity was undersized in relation to its contributing drainage area (see Section 4.2 for images depicting this problem). Lack of detention volume is related to another top-ranking "Poor Design Feature" – *improper elevations of inlets, outlet, berms, etc.* Miscalculations in elevations for the various components of a stormwater facility can cause water to flow into places where it should not, create ponding where ponding is not intended, erode areas that are not properly reinforced, or even allow water to completely bypass the BMP system. While these "Poor Design Features" were detected, field surveys could not determine if improper elevations were due to poor design or poor construction. It is important to note that installing a BMP with all the proper elevations is as imperative as designing the facility correctly. This construction issue is discussed in more detail in Section 4.

There are a number of other design problems that were not observed as frequently, but should be avoided in future BMP designs. Figure 15 shows photographs of BMPs that illustrate these features.

BMP does not treat more polluted parts of site. This infiltration trench treats just the roof, but the parking lot is left untreated.



Inlet not well reinforced to prevent erosion. This infiltration trench inlet is relatively steep – some inlet protection is required to prevent erosion here.

Poor placement of BMP. These paver blocks are down-gradient from asphalt portions of parking lot, accumulating fine sediment from the asphalt over time.

Sewer or other utility infrastructure in BMP. This sanitary sewer manhole located below elevation of BMP outlet, therefore at risk of taking in water and overflowing to surface.

Figure 15. Additional noteworthy design issues identified in the survey.

 **Vegetation too close to inlet pipes.** This inlet pipe has no flare-end, rip-rap apron, or other hard feature to keep vegetation from growing next to pipe. Vegetation can block incoming water, causing sediment to accumulate in pipe (**see photo on right**).	

Figure 15 (continued). Additional noteworthy design issues identified in the survey.

Section 4. Construction Issues

A stormwater BMP may be immaculately designed on paper, but is at risk of failing if those designs are not correctly implemented during construction. This BMP survey identified a variety of signs suggesting that BMPs were not properly installed during construction of the site. This section highlights the following indicators of stormwater BMP construction problems found in the field:

- Deviations from design plans;
- Discrepancies between planned and constructed water quality volume;
- Grading problems; and
- Filter media problems.

Section 4.1. Deviations from Design Plans

When approved stormwater design plans were available, they were used during the field survey to compare with observed BMP conditions. Inconsistencies between the plan and field observations and measurements suggest that some features were not constructed properly. Deviations from design plans during construction can result in minor reductions in stormwater treatment or serious malfunctions of the BMP.

A total of 72 BMPs were compared to their approved design plans. Approximately half of this subset (47%) were observed to have one or more deviations from the design specifications shown on the site plan. Table 9 shows how BMPs with design plans deviated in the field from their approved designs and lists the types of deviation involved.

Table 9. Design plan deviation examples.

Category	% of Subset (n=72)	Examples of Deviations
Vegetation composition	18%	• Fewer plants, less diversity of plants • Wetland plants missing – no aquatic bench
Dimensions and/or volume	13%	• No retention volume • No detention of runoff • Under sized dimensions / volume
Soil type	10%	• Excessive clay in soil • Soil compacted – reduced permeability • Clogged gravel • Missing filter materials (e.g., sand and gravel)

Table 9 (continued). Design plan deviation examples.		
Category	**% of Subset (n=72)**	**Examples of Deviations**
Pretreatment type and/or size	8%	• Pretreatment feature missing, changed, filled in or blown out
Inlet type, number, and sizing	8%	• Curb cuts too small • Missing inlets • Extra inlets
Outlet type, number, and sizing	6%	• Missing gravel diaphragm • Missing underdrains
Low-flow channel	3%	• Channel created by erosion

Section 4.2. Discrepancies between Planned and Constructed Water Quality Volume

As noted above, one of the chief construction issues noted in the field survey was that practices lacked retention or detention volume or were not constructed as per dimensions shown on the plans. The field survey also tried to gage whether practices were sized correctly by measuring BMP dimensions in the field (surface area and depth to a water quality orifice or outlet device). These "observed" water quality volumes (WQv) were compared to the "calculated" volume based on Virginia's current standard, as follows:

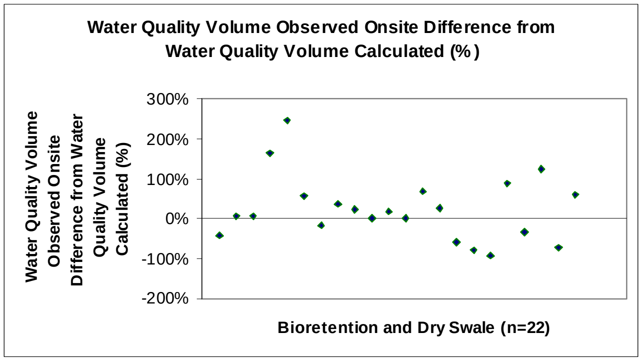
WQv = 0.5 inch X impervious area in the BMP drainage area

Figure 16 shows the results of this comparison for bioretention and dry swales, infiltration, water quality dry pond, and constructed wetland practices. The data in the plots are shown as the percent difference between the observed (field-determined) WQv and the calculated WQv based on impervious cover. In the plots, the horizontal line indicates that the observed and calculated WQv are the same; points below the line indicate that practices may have been built with a smaller volume than designed, and points above the line indicate possible over-sized practices.

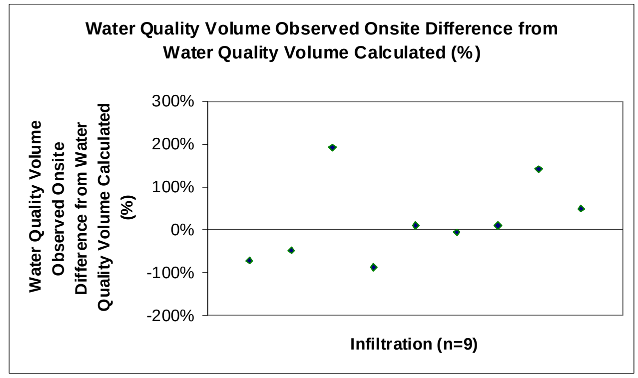
This analysis was not possible for all BMPs in the field survey, as some sites lacked the base data to conduct the analysis. Furthermore, only BMPs where the drainage area was discerned from field measurements, approved plans, or local government data were included. Also, this analysis made several assumptions, such as the application of the 0.5 inch sizing rule. As such, the results represent a general indication of over or undersizing for a good cross-section of BMPs.

Given these caveats, it appears from Figure 16 that there are incidents of both over and undersizing of BMPs and that many BMPs are properly sized. Since undersizing is a particular performance issue, it is interesting to note that the incidence of undersizing may be a bit more common for bioretention and dry swales (roughly 30% of the analyzed data). Figure 17 shows several photographs of BMPs that are likely undersized. There are many plausible explanations for both over and undersizing of BMPs. The chief take-home point is that local programs need to be aware of this issue during construction inspection and approval of as-built plans.

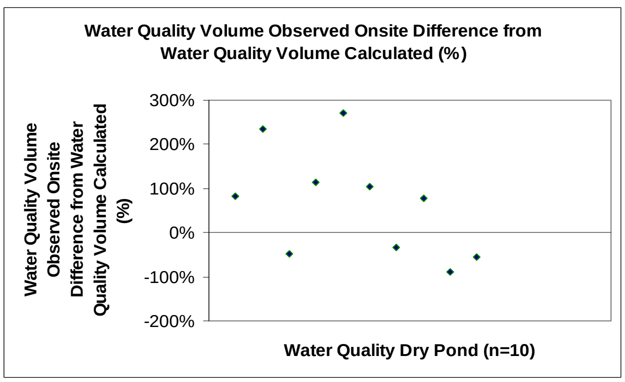
(A)



(B)



(C)



(D)

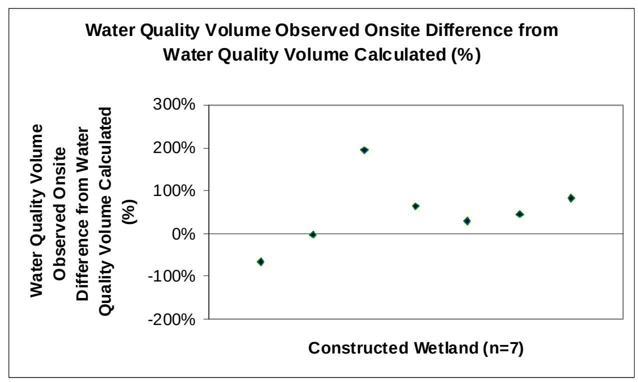


Figure 16. Percent difference between the calculated WQv (ft^3) and observed on-site WQv (ft^3) for: (A) bioretention and dry swale, (B) infiltration, (C) water quality dry pond, and (D) constructed wetland practices. The calculated WQv is based on the existing Virginia standard of 0.5” x impervious cover. The observed WQv is based on field measurements of treatment surface area and depth of storage to a water quality orifice or outlet. The horizontal line indicates that the calculated and observed volumes are the same. Points below the line indicate that practices may have been built with a smaller volume than planned, and points above the line indicate possible over-sized practices.

Observed WQv is 93% less than calculated WQv

Observed WQv is 32% less than calculated WQv

Figure 17. Undersizing is a more likely phenomenon when BMPs are squeezed into tight spaces (left) and where side slopes encroach on the filter surface area (right).

Section 4.3. Grading Problems

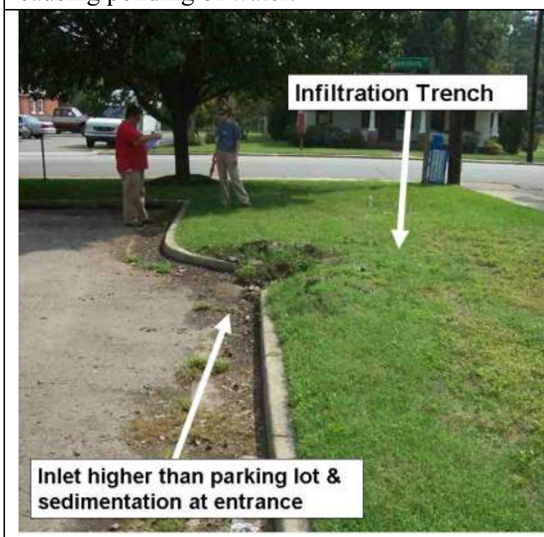
Proper grading within the contributing drainage area and the BMP facility is one of the most important factors that determines the BMP's ability to properly treat the intended runoff volume and rate. A significant portion of the BMPs surveyed exhibited signs of improper grading during construction and/or BMP structure components that were set at improper elevations. Although it was difficult to determine if these failures were the result of poor construction or poor site planning, *grading/elevations* issues were noted in 25% of the sites as a "Poor Design Feature" and appear to be common problems in the study area.

As illustrated in Figure 18, this category of "Poor Design Feature" consists more specifically of problems with:

- Ponding in the BMP near the inlet;
- Inlet too high – preventing flow from the landscape into BMP;
- Elevations within BMP prevent full use of treatment area;
- Grading problems in CDA;
- Grading problems in BMP;
- Improper elevations of BMP structure (e.g., inlet, outlet, berms); and
- Ponding of water and/or sedimentation in parking lot.

The rip-rap in this detention pond is set lower in the ground than the outlet riser in the background, causing ponding of water.

The runoff from this parking enters one curb cut that is very close to the dry swale's outlet.



The stone at this inlet is mounded to an elevation that is higher than the pavement, potentially blocking flow into the bioretention.

Figure 18. Examples of poor design features associated with grading and elevations.

Section 4.4. Filter Media Problems

The filter media for most BMPs appeared to be functioning properly and installed according to design specifications. The filter media components for only 10% of the BMPs deviated from what was shown on their design plans. Of those, some BMPs were missing filter media components, such as a layer of gravel or sand in the soil media. The most common filter media problem was an overabundance of clay in the soil media. In some instances, BMP soil media appeared to have been overly compacted by equipment during construction and/or mowers over time, decreasing the potential for infiltration (see Figure 19 below).

Figure 19. Compacted bioretention soil (left) with high clay content (right).

Section 5. Maintenance Issues

As noted earlier, nearly half of the BMPs needed maintenance (the highest ranked general performance issue of the study) and 14% had no access for maintenance. Figure 20 shows the percent of BMPs that needed maintenance by BMP type. For instance, 100% of level spreaders, 50% of permeable pavement, and 35% of bioretention areas were in need of some type of maintenance. Maintenance is obviously a very critical issue with BMP performance. This is tied to both programmatic issues (e.g., inspections and enforcement) and design issues (see Section 6 for a detailed discussion of local programmatic topics).

Figure 21 illustrates more detailed maintenance issues revealed by the field survey. Clogging of inlets and outlets is more common than erosion or structural problems at inlets and outlets. Of the 78 BMPs that reported having pretreatment measures, lack of sediment removal and conveyance of sediment from the pretreatment to the BMP were the most widespread issues. Maintenance issues, and specifically sedimentation, are common performance problems that have been documented in several studies (Roberts, 1992; Lopez, 2003; NC Division of Water Quality, 2005; Wahl, 2007; Weinstein, Crawford and Garner, 2008). A significant percent of the sites with pretreatment also reported that the pretreatment practices were being bypassed (18%) or that the pretreatment practice was not functioning (16%).

The field survey also looked at the health of vegetation within BMPs. Stressed or dead ground cover and sparse vegetative cover were the most frequent of the vegetation issues (11%). Half of these cases were found in bioretention and dry swales.

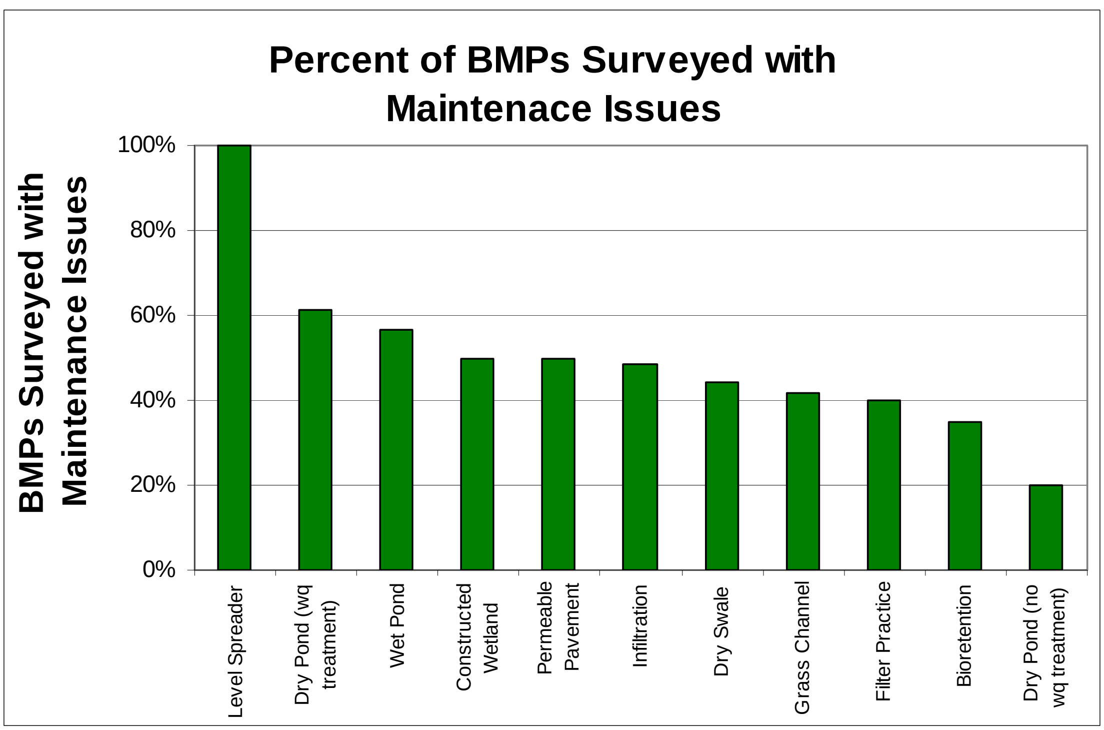
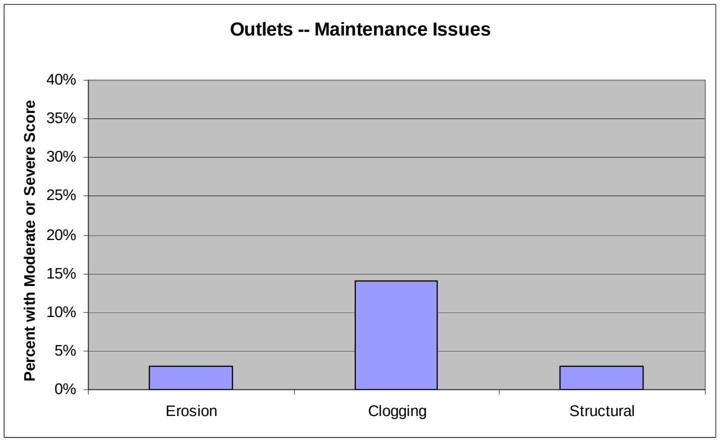
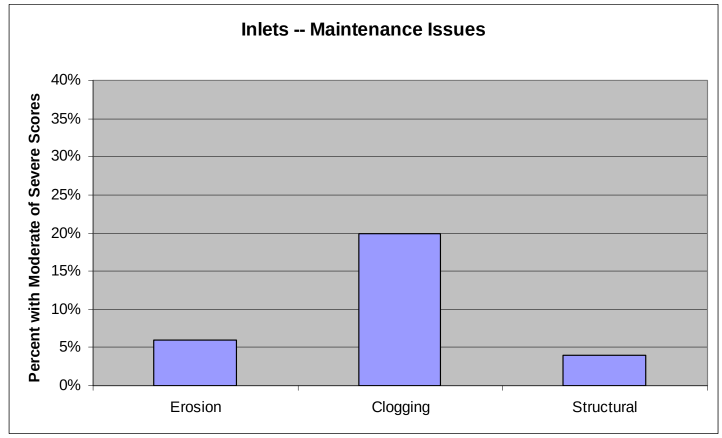


Figure 20. Percent of BMPs surveyed with maintenance issues by BMP type (n=87).

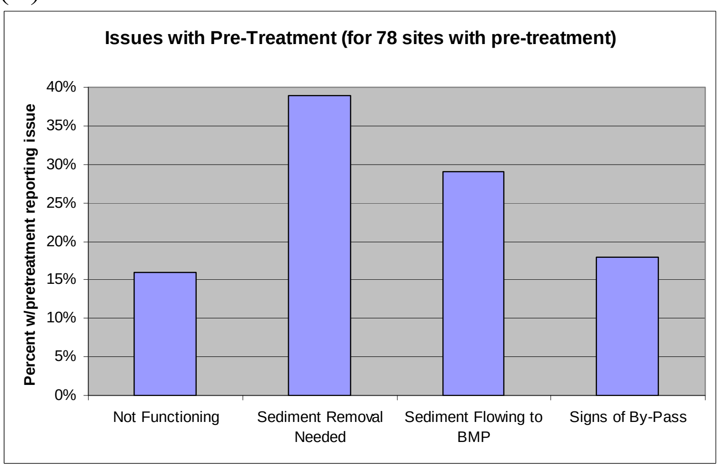
(A)



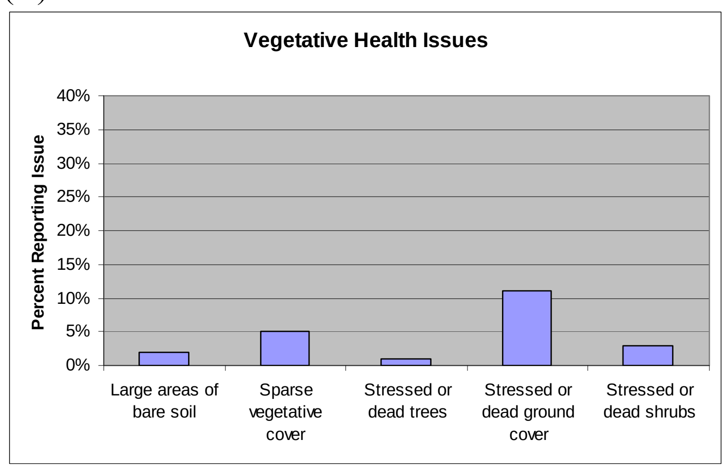
(B)



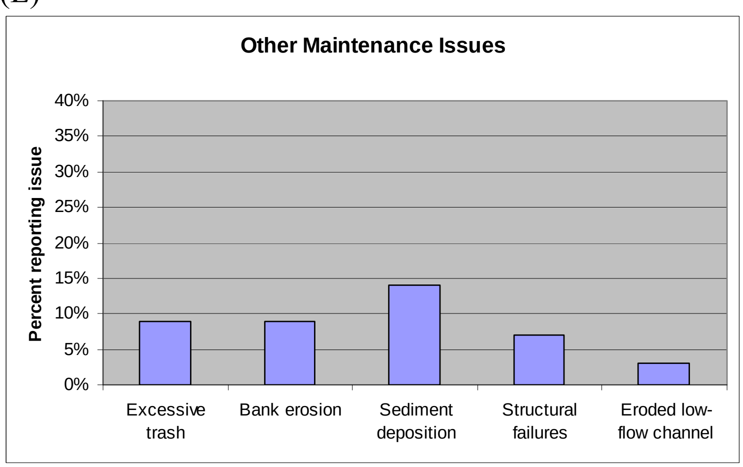
(C)



(D)



(E)



(A) Maintenance issues at outlets;

(B) Maintenance issues at inlets;

(C) Maintenance issues with pretreatment;

(D) Vegetative health maintenance issues; and

(E) Other maintenance issues.

Figure 21. Percent of BMPs with maintenance issues: (A) maintenance issues at outlets; (B) maintenance issues at inlets; (C) maintenance issues with pretreatment; and (D) vegetative health issues; and (E) other maintenance issues.

Other BMP maintenance issues revealed by the field survey include: sediment deposition (14%), excessive trash (9%), Figure 22 shows the percent of BMPs with moderate or severe sediment deposition problems sorted by BMP type.

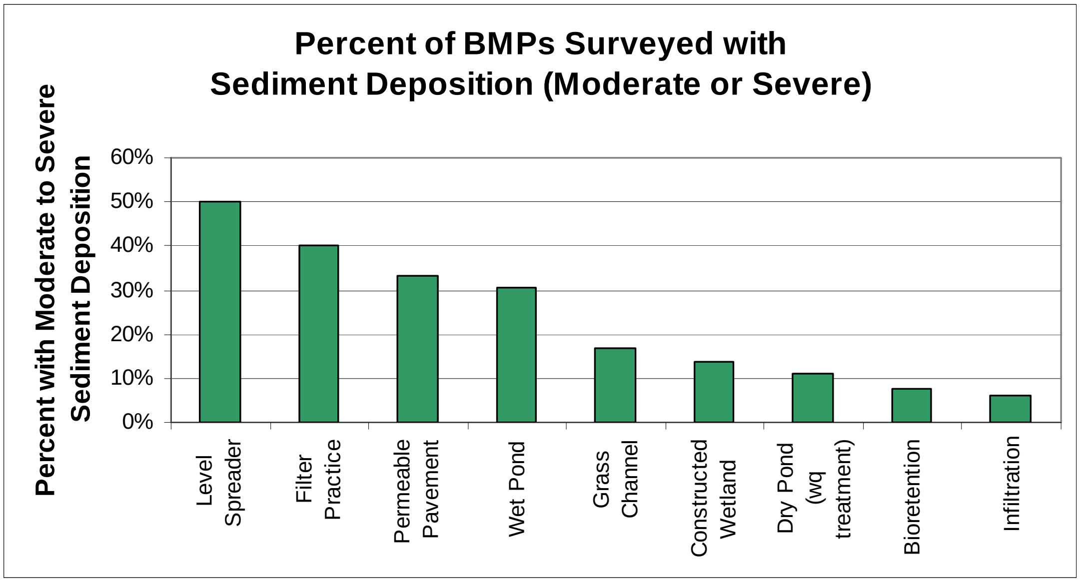


Figure 22. Percent of BMPs surveyed with moderate to severe sediment deposition maintenance issues by BMP type (n=27).

It is clear that BMP maintenance will continue to be a significant issue that needs to be addressed through both design and programmatic improvements. Figure 23 shows photographs of several common maintenance issues revealed by this study.

Trash accumulation is strong evidence for poor BMP maintenance.

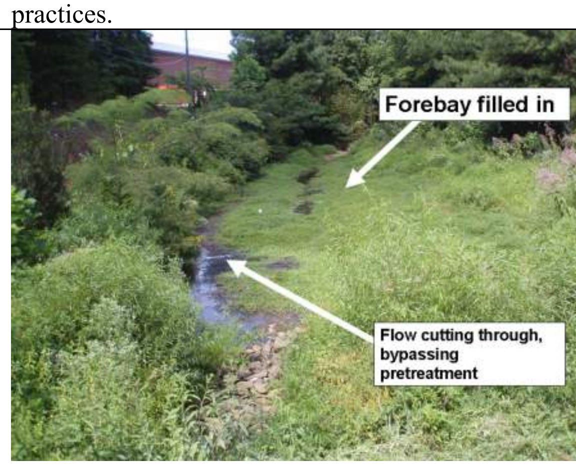
This wet pond outlet is severely clogged with trash and leaf debris, which raises the water surface elevation and decreases storage.

Figure 23. Common maintenance issues identified through the study.

High velocity flow from the impervious channel caused significant erosion below the BMP and outlet protection is needed to protect the channel from further erosion.

This pond has been "overly" maintained – nearly all vegetation was eliminated by excessive mowing practices.

BMPs accumulate sediment and periodic sediment removal is necessary to combat sediment deposition. Sediment removal for BMPs, such as paver blocks, can be challenging.



Unintended BMP channelized flow occurs when sediment deposits fill in the BMP.

This fence was built around the BMP without any gate. Lack of maintenance access can be a deal breaker when it comes to BMP upkeep.

This detention pond became so over-run with vegetation that it disappeared and was invisible to the landowner, as well.

Figure 23 (continued). Common maintenance issues identified through the study.

BMP modification can reduce the functionality. This infiltration basin was covered by a plastic liner and converted to a visual feature. The owner was unaware of the BMP's purpose and function.

So much mulch was added to this bioretention that it is higher than the level of the inlet. The basic functions of a BMP need to be kept in mind when maintaining BMPs that also serve as landscaping.

Vegetated BMPs can become dominated by a monoculture of invasives, if not maintained.

Inlet pipe sedimentation and vegetation accumulation is a common maintenance issue.

Figure 23 (continued). Common maintenance issues identified through the study.

 Runoff has channelized a pathway through the bottom of this dry detention pond.	 Steep slopes coupled with poor vegetative cover is a recipe for erosion problems that can be difficult to remedy.
 Minor structural problems can circumvent the treatment mechanism, such as with this broken level spreader.	 Inlet channels can erode when channel lining is inappropriate or installed improperly.

Figure 23 (continued). Common maintenance issues identified through the study.

Section 6. Local Stormwater Programs Assessment

The purpose of this section of the report is to assess how local stormwater programmatic issues ultimately influence BMP performance in the field. Local program planning, staffing, design guidance, inspections, tracking, interdepartmental coordination, and other elements will all influence the success of BMP design, installation, and maintenance in the field.

In order to identify some of the strengths and weaknesses of local stormwater management programs in the James River basin, the *Extreme BMP Makeover* partners conducted assessments of four local programs spread throughout the watershed, each characterized by different demographics and scales of urban development. The smaller two localities are permitted as Phase II Municipal Separate Storm Sewer Systems (MS4s) under the National Pollutant Discharge Elimination System (NPDES) program, and the larger two are Phase I permittees. The experiences of these four communities, collectively, can provide lessons to other MS4s and non-regulated local programs in the James River basin and beyond.

Section 6.1. Methodology

Stormwater managers from "Early Adopter" communities in the James River basin were solicited to volunteer for this assessment. Four localities agreed to participate. The assessments, which took place from October 2008 to January 2009, were based on in-depth interviews with stormwater management personnel from each locality. The interviews were based on the Center for Watershed Protection's "Post-Construction Program Self-Assessment," one of the eight tools produced in 2008 in conjunction with the national guidance manual, *Managing Stormwater in Your Community: A Guide for Building an Effective Post-Construction Program* (Hirschman and Kosco, 2008). This manual, and the associated tools, can be downloaded at: www.cwp.org/postconstruction.

The self-assessment tool addresses the following elements of a local program:

- Program development;
- Land-use planning as it relates to stormwater management;
- Stormwater management criteria;
- Stormwater ordinance;
- Stormwater guidance manuals;
- Plan review process;
- Inspection of stormwater BMPs during construction and initial installation of permanent BMPs;
- Inspections and maintenance of permanent stormwater BMPs;
- Tracking, monitoring, and evaluating BMPs; and
- Public outreach.

The self-assessment was sent to each of the participating localities about a month prior to the scheduled interview. It was suggested that the self-assessment be completed by various staff involved in the stormwater management program, so as to represent a diversity of perspectives about the program. When the self-assessment was completed, Center for Watershed Protection staff and project partners conducted an in-person interview with those staff members who had completed the self-assessment. During these follow-up interviews, which each lasted approximately three hours, each of the topics listed above was discussed. The discussions tended to focus more heavily on program elements that the local participants score themselves low on in order to explore the relevance of that element to the specific program. The interviews also covered elements that were unique to each locality. In this report, however, all answers provided in the written self-assessment as well as the interviews were taken into account.

All those involved in these assessments were assured that the name of their locality, their completed self-assessment forms, and the particulars of the interview discussions would be kept *confidential*. Therefore, this report speaks about these four local stormwater management programs only in general terms, without identifying the specific localities that participated.

This study focused in great detail on four local stormwater programs in the James River basin. It should not be interpreted, therefore, as an overview of all stormwater programs in the watershed, in Virginia, or in the Chesapeake Bay states. Instead, the findings of these assessments identify differences and similarities between the localities, as well as specific program components that have proven to be beneficial or problematic for some of these "Early Adopters."

Each subsection below addresses one of the program elements covered in the self-assessment and the interviews.

Section 6.2. Program Development

Each local program appears to have a good base of information about local geographic and water quality characteristics, but only half have assessed demographic and community characteristics and their potential implications for stormwater management. Each of the four localities has established measurable goals to drive the stormwater program, mostly based on regulatory requirements. Goals vary between localities and include: nutrient reduction goals, goals based on total maximum daily load (TMDL) plans, and target numbers of BMP inspections. Despite the fact that each locality has established its own set of goals, only one claimed to have a written stormwater management program plan in place and none had an implementation plan for phasing in staff and funding.

Mechanisms used to fund each stormwater management program vary somewhat between the localities:

- 2 programs are funded primarily through general fund;
- 1 program is funded through general fund and development application fees; and
- 1 program is funded by stormwater utility fees.

Those funded primarily through the general fund have been experiencing budget cuts for their stormwater programs, some quite severe, due to the downturn in property tax revenues. Conversely, the locality that generates funds through a stormwater utility has seen a steadier stream of funds for its stormwater program and has plans to incrementally increase revenues from the utility as infrastructure needs and water quality initiatives increase over time.

Identifying which departments and staff members have responsibility for various aspects of stormwater management is a critical component of a local program. Among the four localities, three split roles and responsibilities for stormwater between two or more departments. In these cases, different departments tend to be responsible for plan review and construction-phase inspections versus post-construction functions, such as long-term BMP inspections and maintenance. The interviews revealed that stormwater staff, including managers, did not have a complete understanding of or familiarity with the program elements covered by other departments. While this split in department responsibilities may be the most practical choice for many local government structures, it appears to detract from the sense of a "comprehensive" program.

Unique Feature: *One locality charges a special fee for each new subdivision that is developed (about $100 per lot). These funds allow the local government to inspect and correct any major stormwater BMP problems that may develop in those subdivisions in the future. The home owners associations (HOAs) are still responsible for regular maintenance such as trash removal and landscaping.*

One approach to enhance coordination and communication between staff in separate departments is to conduct cross-training activities for, for example, plan reviewers and stormwater inspectors or erosion and sediment controls (ESC) inspectors and post-construction BMP inspectors. This enables all staff involved in the stormwater management program to receive the same training and information and creates better consistency between the departments. None of the four localities conduct such training events specific to the stormwater management program. In general, stormwater management training events appear to be minimal among these localities, even *within* departments. This may be less of a disadvantage for localities in which all stormwater management staff work within one department.

Section 6.3. Land-Use Planning

Several questions were asked of the four localities about how they incorporate stormwater management and water quality protection goals with land use planning. Half of the localities include stormwater management program objectives in their Comprehensive Plans. The other two localities do not consider stormwater management directly in their Comprehensive Plans, perhaps because stormwater managers were not involved in updating the Plans. The assessments did find, though, that all four localities have developed watershed management plans for specific watersheds within their jurisdictions.

Another venue for promoting stormwater management goals in future development are pre-application meetings with potential development applicants. Three out of four of the localities involve stormwater managers in pre-application meetings. This gives stormwater managers and land use planners an opportunity to encourage the developer to consider water quality and stormwater management practices early in the design process.

At least three of the four localities have instituted land-use planning strategies that encourage development within specific areas of their jurisdiction, with the intention of concentrating development in already urbanized areas. One locality allows flexibility in stormwater management criteria where redevelopment and infill is a priority for the local government. However, sometimes these areas of concentrated development are within watersheds of sensitive or impaired streams. While concentrating development in specific areas (rather than allowing sprawled development) can lead to better water quality on a regional scale, this land-use strategy is not always coordinated with goals to preserve and/or enhance water quality in specific watersheds. As is true in most of the country, this type of watershed-based land use and zoning is not yet a reality in the localities assessed in this study. Several methods used by some of these localities to provide better water quality protection in sensitive watersheds are discussed in the following section.

One issue that has not been considered thoroughly by the localities, but that has implications for stormwater management, is climate change. Within the James River basin, localities in the Hampton Roads area near the ocean will likely be the first to consider how to adapt their stormwater management techniques to the impacts of climate change (e.g., storm distributions, frequencies and intensities and implications for infrastructure and design).

Section 6.4. Stormwater Management Criteria

In Virginia, stormwater management standards are primarily driven by state regulations, administered by the Department of Conservation and Recreation. In a few cases, localities have developed additional stormwater management criteria that go above and beyond the state-wide standards. Several questions were asked in these assessments about each locality's specific approach to stormwater management criteria and standards.

Each of the four localities has identified sensitive waters and/or natural areas within their boundaries. These sensitive areas include:

- Drinking water supply areas;
- Watersheds with a completed watershed management plan; and
- Impaired waters / waterbodies with TMDLs.

Each locality has also established special stormwater management criteria (usually more stringent than for the majority of new development) for certain areas or situations, including:

- "Hotspots" – sources of high pollution, such as gas stations or vehicle maintenance areas;
- Public projects in TMDL watershed or wetland watersheds (to set a good example);
- Re-zoning cases;
- Areas with established watershed management plan; and
- Drinking water supply areas.

The fact that each of the four localities has developed special stormwater criteria for specific situations is an acknowledgement that certain types of development require greater management of pollution and certain sensitive watersheds are in need of stronger protections from runoff.

Conversely, many localities have acknowledged that complying with stormwater management standards with the use of stormwater BMPs can be very difficult on some sites with very limited space. Three out of four of the localities have created a *fee-in-lieu* option for developers to pay a fee for certain sites that meet specific "feasibility" criteria. In some localities, these fees are assembled over time by the local government to help fund larger-scale water quality improvement projects. Enthusiasm for the fee-in-lieu option varies greatly among stormwater staff. Some staff members feel that accruing funds for watershed-scale projects through these fees is a great benefit, while others worry that the fee-in-lieu system will be abused by applicants and will disproportionally impair certain watersheds. One interviewee suggested that a fee-in-lieu program is only appropriate for redevelopment and infill projects.

> ***Unique Feature:*** *One locality has developed a stormwater criterion that exceeds the state standard for controlling the "channel protection" volume of runoff. This local channel protection standard requires extended detention of the 1-year, 24-hour storm event.*

Stormwater staff members from the four localities were asked several questions about their approach to low-impact development (LID) types of stormwater management. Only one locality actively encourages the use of LID or other innovative stormwater practices during pre-application meetings and during plan review. Of the other three localities, one does not have the support of stormwater staff to promote LID, and two are interested in LID but have not yet developed a plan review system to encourage or incentivize the use of LID practices. The latter issue may be partially rectified by the proposed Virginia Department of Conservation & Recreation (DCR) stormwater regulations, which assign runoff reduction rates to both conventional and innovative practices. However, the local reviewers will still need to become familiar with and encourage the innovative practices during pre-application meetings, assuming the locality wishes to promote (or at least accept) these types of practices.

The topic of Total Maximum Daily Loads was brought up during these assessments. Each locality was asked if their program enforces site-based load limits or special performance standards for development in TMDL watersheds. None of the four localities currently enforces waste load allocation limits for either new developments or redevelopments, but all of them expressed awareness that this may soon be a requirement at the federal or state level. There appeared to be some uncertainty and concern among staff as to how their locality would go about measuring potential pollutant loads and enforcing load limits for development. In the localities assessed, the main pollutants of concern in impaired waterways are bacteria and nutrients.

Section 6.5. Stormwater Ordinance

Each of the four localities has a codified stormwater ordinance that explains the purpose of stormwater management and gives the local government the legal authority to implement the MS4 program, including construction and post-construction minimum measures. Other elements of the stormwater program that are codified in the ordinances vary between the localities. In some localities, the ordinance goes into great detail about specific requirements – such as plan review fees, BMP inspection frequency, and penalties and remedies for non-compliance of BMP maintenance. Other localities only codify the most basic stormwater management rules (e.g., exemptions and waivers, water quantity and quality criteria) and reserve other details for policy documents and guidance manuals that can be revised without action by the elected body.

It was found though, that there are several similarities in the codified stormwater management rules among the four localities. For example, all four localities require a performance bond to be posted prior to the start of construction. This bond is returned to the owner or contractor (whichever posted the bond) once the site has reached final stabilization and has received a final inspection and approval from the locality. This form of financial surety is not an enforcement tool in the strict legal sense, but helps to motivate the developer to implement good erosion and sediment control techniques and proper installation of permanent stormwater BMPs (Hirschman and Kosco, 2008).

***Unique Feature**: One locality releases only a portion of the performance bond when site stabilization has been achieved. The remainder of the bond is retained by the locality for a year, to verify that permanent stormwater BMPs on the site are functioning properly.*

It is interesting to note that, although all four localities require the posting of a performance bond, only two require the submittal of a certified as-built plan prior to the release of the performance bond. Requiring as-built plans can help to certify that permanent stormwater BMPs have been installed and stabilized according to approved plans, in turn ensuring better BMP performance in the long run.

Another requirement that is codified in each of these four localities is the signing of a maintenance agreement, assigning long-term responsibility for the maintenance and operation of all permanent stormwater BMPs. In most localities, these maintenance agreements transfer with the deed to the property, ensuring that new owners are also legally bound to maintain stormwater BMPs on that property. Only two out of four of the assessed localities require that a maintenance plan be filed along with the maintenance agreement document. Such a maintenance plan specifies the tasks and schedules associated with maintaining a particular type of BMP, and can provide a more prescriptive "recipe" for responsible parties to follow. These plans can be attached to deeded maintenance agreements, but they can easily be lost in the deed documents and never actually seen by successive owners. Therefore, it is recommended that they also be included on approved plans and any outreach or educational materials provided to responsible parties.

Section 6.6. Stormwater Guidance Manual

Half of the localities assessed in this study have developed a stormwater guidance manual specific to their local program. The other two localities refer development applicants directly to the statewide Virginia Stormwater Management Handbook developed by the Department of Conservation and Recreation in 1999. This manual provides guidance on BMP designs, basic hydrology and hydraulics computations, and administrative issues regarding compliance with the state stormwater regulations. This state handbook is currently being updated to accommodate new design specifications and the upcoming revisions to Virginia's stormwater regulations. The two localities with their own stormwater guidance manuals generally do not make regular updates to the manuals.

Section 6.7. Plan Review Process

The plan review and approval period is perhaps the most important process for ensuring that a stormwater management plan is well designed for the particular conditions of a site. Once the plan is approved, these design choices are basically "inscribed" for current and future owners of a particular development. Therefore, a thorough and well-organized plan review process can greatly improve the chances of implementing effective stormwater BMPs within a locality.

The plan review processes in all four localities appear to be well organized. Each has a specific schedule for submissions, reviews, and approvals and each has a checklist of plan submittal requirements for applicants to use. Each locality also keeps track of its review process in a database -- two of the localities give access to the public to view this tracking system and the other two localities only allow applicants and internal staff to view the system.

Each of the four localities provides potential applicants with the option of a pre-application meeting, but none have made this mandatory. These meetings give the applicant a chance to get initial feedback from local government plan reviewers on a potential project. This is also a critical step for plans that use site design approaches (e.g., sheetflow to conservation areas, impervious reduction/disconnection, riparian restoration) as part of the stormwater plan since these features need to be considered early in the site planning process. Among the four localities, pre-application meetings are currently being used for only about 10 – 15% of all projects.

***Unique Feature**: The option of an* expedited plan review process *can be made available to applicants for specific situations that are shown to benefit a locality. One local program assessed in this study gives developers this option as an incentive for them to use low-impact development techniques on their project.*

It should be noted that few of the interviewees in this study were actually involved in plan review. This is because, for most of these localities, stormwater management inspectors do not participate in the plan review process. In fact, only one out of the four localities involves post-construction stormwater BMP inspectors in the plan review process. Without a formal process to include stormwater management inspectors in the plan review process, it can be difficult for them to provide input into BMP selection, placement, design, and maintenance plans. This is unfortunate since inspectors of permanent stormwater BMPs have a great deal of insight into what causes BMPs in the field to work well or fail.

Nationwide, each plan reviewer checks an average of 70 to 100 stormwater plans per year (CWP, 2006). Localities assessed in this study were asked about the approximate number of plans being reviewed by each of their plan reviewers on an annual basis. Only two localities were able to provide an estimate (the other two sets of interviewees were not familiar enough with the program, as mentioned above). Both sets of respondents explained that each plan reviewer in their locality reviews more than 100 to 150 plans each year, not including resubmittals of plans for the same project. This indicates that these localities may not have enough staff to conduct a thorough review of all plans that are submitted.

Section 6.8. Inspections and Installation of Permanent BMPs During Construction

Three out of four of the localities have inspectors on staff that specialize in erosion and sediment control (ESC). In the fourth locality, the building inspectors on staff also conduct inspections of ESC practices. Half of the localities felt that they do not have enough ESC inspectors to do a thorough job of inspecting each construction site.

Since ESC inspectors in the majority of assessed localities are in departments or divisions apart from the staff who conduct long-term maintenance inspections of permanent BMPs, an important program element is the degree of coordination between these functions. Half of the localities provide no opportunity for stormwater inspectors (the long-term maintenance staff) to inspect permanent BMPs during active construction, and thus initial installation of permanent BMPs. One locality, however, brings in a stormwater inspector for the final ESC inspection so that person (instead of the ESC inspector) can "sign-off" on the proper installation of the stormwater BMPs. As mentioned earlier, one of the localities has ESC inspectors and stormwater inspectors in the same department. For this locality, it is easier for the two types of inspectors to communicate about stormwater issues on construction sites.

Section 6.9. Inspections and Maintenance of Permanent BMPs

One of the most interesting findings of these assessments is that each local stormwater program has chosen to inspect and maintain a different combination of BMPs. For each locality, Table 10 depicts which BMPs are inspected regularly by local government staff, which BMPs are maintained by local government staff, and if/how the enforcement of BMP maintenance is prioritized.

Table 10. Inspection and Maintenance of BMPs in Four Localities

	BMPs Inspected	BMPs Maintained by the Local Program	Prioritization
Locality # 1	• All BMPs (public and private) in jurisdiction receive cursory inspection every 3 years • About 1200 BMPs in total	• All BMPs on local government property • BMPs in subdivisions – only major maintenance tasks (HOA responsible for day-to-day)	• Only most urgent maintenance problems are addressed for compliance
Locality # 2	• All BMPs on public properties and most commercial, industrial, and subdivision sites • About 500 BMPs in total	• All BMPs on public properties and most commercial, industrial, and subdivision sites • About 500 BMPs in total	• All inspected sites are treated with equal priority
Locality # 3	• Only BMPs on local government property receive inspection annually • Inspections of private BMPs are complaint-driven (600 private BMPs)	• Only BMPs on local government property	• All inspected sites are treated with equal priority
Locality # 4	• All BMPs (public and private) in jurisdiction receive inspection every 3 years • About 400 BMPs in total	• Only BMPs on local government property	• All inspected sites are treated with equal priority

Each of the four localities uses a basic checklist for BMP inspections and keeps long-term records of inspection results. See the following section for information about data tracking.

It appears from these assessments, that maintenance problems in BMPs that are not maintained by the locality ("private BMPs") are very rarely enforced with penalties for non-compliance. Two of the four localities do not have civil penalties for maintenance non-compliance and the other two were generally uncertain as to what the ultimate penalties to landowners would be for not correcting maintenance problems. This suggests that even if the stormwater ordinance in the latter two localities includes civil penalties, those penalties would rarely be enforced by stormwater staff. It is possible that most maintenance problems are resolved before reaching the point where penalties would be incurred.

***Unique Feature**: Following each inspection, one locality sends out a letter to the landowner responsible for the maintenance of stormwater BMPs. This letter lists maintenance needs (major and minor) and shows photographs of the problems. These letters serve not only to alert landowners, but to also help raise their awareness of the fact that they own a stormwater facility.*

Section 6.10. Tracking, Monitoring, and Evaluating BMPs

A great deal of information needs to be catalogued to keep track of stormwater BMP locations, inspections, maintenance actions, and general BMP performance over time. These assessments found that all four of the participating localities have good databases of basic information about stormwater BMPs that have been installed within the jurisdiction. Two of the four have even connected their BMP database to GIS mapping systems, so that BMP data (e.g., inspection reports) and location can be viewed integrally.

There is a good deal of variety, though, in the types of stormwater infrastructure that have been mapped in GIS. All four localities have at least mapped the general location of each BMP that they inspect. Some have also begun to map storm drain inlets and outlets, pipes, culverts, and other conveyance systems. This allows stormwater staff to visualize and understand the conveyance systems over whole sites and entire "sewersheds."

There is also a lot of variety in how each locality conducts monitoring of water bodies and BMP outfalls. Two of the localities (both are Phase 2) have developed partnerships with citizen water quality monitoring groups to assess streams and other water bodies within their jurisdictional boundaries. This helps these localities collect monitoring data for a larger number of streams and rivers than would otherwise be possible, and it also helps fund the equipment and coordination of the monitoring group.

None of the assessed localities have developed a strategic plan to outline goals and objectives for their monitoring program. It is likely that their main motivation for conducting these monitoring efforts is to comply with NPDES permit requirements.

Section 6.11. Public Outreach

Educational and outreach initiatives for the public can improve stormwater stewardship, can increase compliance with BMP maintenance requirements, and can help garner public support for a local stormwater management program. All four localities conduct some form of public outreach. Each conducts two or more outreach events per year and each locality has developed public demonstrations of innovative stormwater management practices to serve as examples for their community.

At least one of the four localities has developed special programs to reach out specifically to Home Owner Associations (HOAs) about proper maintenance of their stormwater BMPs. And at least two of the localities have created public education partnerships with other MS4s in their vicinity. By combining their individual education funds, localities participating in these partnership organizations are able to develop stronger and broader stormwater outreach initiatives than they would be able to on their own.

Based on the findings of this local assessment, we have made several recommendations of local stormwater program components and functions that may enhance the design, construction, and maintenance of stormwater BMPs in the James River basin and beyond. See Section 7 to view these Stormwater Programmatic Recommendations.

Section 7. Recommendations

The recommendations in Table 11, for design, construction, and maintenance issues, are divided into two categories: BMP Design Recommendations include steps that can be taken through design standards and specifications and during the plan review process to improve BMP performance. Stormwater Programmatic Recommendations are actions that local stormwater programs can consider for improving BMP performance through guidance, requirements, inspections, standard forms and procedures, and other program elements.
Additional guidance for the development and implementation of local stormwater programs can be found in Hirschman and Kosco (2008).

Table 11. Design and programmatic recommendations for specific design, construction, and maintenance issues.

Issue	BMP Design Recommendations	Stormwater Programmatic Recommendations
DESIGN ISSUES		
BMP Geometry	• Amend current standards for length/width ratio and flow path, and add a standard for shortest flow path • Encourage multi-cell designs • Develop more specific standards for curb cut designs	• Address BMP geometry and flow path issues during pre-design meetings because they may affect site grading issues
Pretreatment	• Develop more prescriptive standards for pretreatment design • Add staff rods or measuring devices to pretreatment for quick visual indication of clean-out level	• Include specific pretreatment maintenance tasks in maintenance plan and maintenance agreement • Ensure that pretreatment is part of construction and maintenance inspections
Filter Media	• Continue to refine filter media standards so that media is readily available and relatively simple to test • Require that filter media be certified to meet appropriate standards	• Encourage or require media from qualified vendors that periodically test the media according to standards • Carefully record track record of various media types versus BMP performance and maintenance issues
Other Design Issues	• Require that water quality BMPs be utilized for a substantial portion of a development site • Review design standards for placement of BMPs that can clog from upgradient sediment (e.g., permeable pavement) • As proposed standard indicates, promote multiple depth zones in stormwater wetlands to avoid monoculture BMPs	• Revise plan review procedures that lead to a good BMP treating a small or inconsequential part of the site • Enhance local BMP landscaping and plant lists to avoid monoculture BMPs • Include proper sizing and elevations as part of construction inspections and approval of as-builts

Table 11 (continued). Design and programmatic recommendations for specific design, construction, and maintenance issues.		
Issue	**BMP Design Recommendations**	**Stormwater Programmatic Recommendations**
DESIGN ISSUES		
BMP Sizing	• Consider creating special detention volume criteria or other stormwater management criteria for sensitive watersheds (e.g., TMDL streams and water supply areas)	• Ensure that plan reviewers are aware of any special stormwater management criteria that may be applicable to sensitive watersheds (e.g., water supply areas) or certain development types (e.g., maintenance garages)
General Programmatic Issues	• Ensure that BMP guidance manuals include most up-to-date stormwater design criteria, including criteria for sensitive watersheds or other special situations	• Encourage the use of pre-application meetings to discuss stormwater management considerations early in the design process, especially for LID • Allow post-construction stormwater staff to provide at least one review of stormwater plans prior to plan approval • Ensure there are enough plan reviewers on staff to provide thorough review of all site plans (no more than 100 plans per reviewer per year)

Table 11 (continued). Design and programmatic recommendations for specific design, construction, and maintenance issues.		
Issue	**BMP Design Recommendations**	**Stormwater Programmatic Recommendations**
CONSTRUCTION ISSUES		
Discrepancies from Design Plan	• Require that critical design information be clearly portrayed on construction plans	• Require and approve as-built BMP plans (for localities that do not already do this) • Conduct training for inspectors and contractors • Conduct inspections at critical periods during initial BMP installation
Sizing/Storage Volume	• See above under "Discrepancies from Design Plan"	• Include sizing and elevations in inspections during BMP installation and require that they are accurately shown on as-builts
Grading	• See above under "Discrepancies from Design Plan"	• Correct even small grading discrepancies in the CDA, especially for curb cut designs
Filter Media	• Simplify the design and procurement of filter media (e.g., utilize qualified vendors)	• At pre-construction meeting, ensure contractor is aware of the sensitivity of filter media in terms of construction sequence, use of equipment (avoid compaction), and proper media • Require inspection of media before it is installed in the BMP
General Programmatic Issues	• See Section 6	• Allow post-construction stormwater staff to perform inspections during installation of permanent BMPs (at least for final inspection) • Ensure there are enough ESC inspectors on staff to provide thorough inspection of all construction projects • Conduct cross-training activities for ESC and post-construction stormwater staff to share knowledge with each other

Table 11 (continued). Design and programmatic recommendations for specific design, construction, and maintenance issues.		
Issue	**BMP Design Recommendations**	**Stormwater Programmatic Recommendations**
MAINTENANCE ISSUES		
Lack of Maintenance Access	• Include maintenance access standards in design manuals and as part of maintenance agreements and Operation and Maintenance (O&M) plans	• Ensure proper maintenance access during plan review • Require that maintenance agreements transfer with deeds
Clogging of Inlets and Outlets	• As part of design, include features to prevent clogging, such as rip-rap or stone aprons and elevation changes between pipe and basin inverts	• Require that responsible parties address maintenance issues regularly, before they become more serious and more expensive to fix
Lack or Failure of Pretreatment	• Include specific pretreatment design options and details in specifications • Ensure that there are proper "drops" or elevation changes (e.g., 4") between pavement edge and rock or stone used for pretreatment (especially as curb cuts) • Design for easy sediment removal and disposal (provide for on-site disposal area if necessary) • Add staff rods or measuring devices to pretreatment for quick visual indication of clean-out level	• Include pretreatment in construction or BMP installation checklists • Include specific pretreatment maintenance tasks in maintenance agreements • Confirm pretreatment during BMP installation inspections
Sediment Deposition	• See pretreatment recommendations above • Design for a reasonable level of sediment accumulation without compromising BMP function • Add staff rods or measuring devices to BMP for quick visual indication of clean-out level	• Encourage or require responsible parties to establish an escrow or maintenance fund so that financial resources for non-routine maintenance are available • Consider creating special outreach program targeting Home Owners Associations

Table 11 (continued). Design and programmatic recommendations for specific design, construction, and maintenance issues.		
Issue	**BMP Design Recommendations**	**Stormwater Programmatic Recommendations**
MAINTENANCE ISSUES		
Vegetation	• Include BMP planting or landscaping plan for all or most BMPs; ensure plan addresses maintenance through time • Establish target vegetative communities and aesthetics for 1-year, 5-year, and ongoing timeframes so owners and local staff know what the expectation is as the vegetation matures	• Provide training for maintenance inspectors and responsible parties on expectations and tasks involved with vegetative maintenance
Erosion of Embankments or Low-Flow Channels	• Ensure proper outlet protection and channel lining during plan review; use energy dissipators where needed • During design phase, require stable side slope grades	• Use performance bonds or other tools to ensure that vegetation is well established and low-flow channels are functioning
Trash		• Encourage adopt-a-pond and BMP stewardship practices • Ensure owners and responsible parties are responsible for trash removal and other routine tasks through maintenance agreements
General Programmatic Issues	• See Section 6	• Develop a clear BMP inspections and maintenance program with specific goals and strategies, including how to resolve maintenance violations on private properties • Use checklist for BMP inspections and maintain long-term inspection records for each BMP • Enforce non-compliance of BMP maintenance requirements in a timely manner

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Appendix A: BMP Inventory Data Attribute Categories

Attribute Category	OPTIONS	DESCRIPTION
CWPBMP_ID		Unique CWP Identifier
CTY_COUNTY	JCC, Albemarle, Chesterfield, Norfolk, Virginia Beach, etc	City or county the BMP is located in
GEOG_REG	AB (Albemarle), RI (Richmond), CP (Chesapeake Area)	Location in James River basin
JDCTN_CODE	CH (Chesapeake), HA (Hampton), NO (Norfolk), VB (Virginia Beach), NN (Newport News), PM (Portsmouth), JC (James City County), HC (Henrico County), CC (Chesterfield County), AC (Albemarle County), CV (Charlottesville)	Jurisdiction code based on the city or county
BMP_TYPE1	BR (Bioretention), CW (Constructed Wetland), DS (Downspout Disconnection), ED (Extended Detention Pond), FP (Filtering Practice), GC (Grass Channel), IN (Infiltration), OT (Other), PP (Permeable Pavement), PR (Proprietary Device), UG (Underground), WP (Wet Pond), WS (Wet Swale)	BMP type based on CWP designations in the Runoff Reduction memo
BMP_TYPE2	Varies	BMP type from city/county GIS data
CODE	Varies	Code based on BMP_TYPE1 and GEOG_REG
NAME	Varies	Location name of the BMP (e.g. Popeyes, Auto Zone, Windhill Subdivision, etc)
ADDRESS	Varies	Address of the BMP
BMP_ID_NO	Varies	BMP ID # (if provided) in the city/county GIS data
PARCEL_NO	Varies	Parcel Identification Number
TAX_MAP_NO	Varies	Tax Map Number
INST_DATE	Varies	Install date or approval date of the BMP
INSP_DATE	Varies	Date the BMP was last inspected
PLAN_ID_NO	Varies	BMP plan ID number(s)
RSPNSBLTY	County, Private, Federal, State	Maintenance responsibility
DRNG_AREA	Varies	Drainage area to the BMP in acres
IMP_AREA	Varies	Impervious area treated by the BMP in acres
LAND_USE	RES (residential), COM (commercial), IND (industrial), ROAD (roadway), AG (agriculture), MI (mixed) INT (Institutional) TRAN (Transportation) REC (Recreation)	Land use in the drainage area of the BMP
NOTES	Varies	Additional notes and comments

Appendix B: BMP Evaluation Form

FACILITY ID: _____	**REGION:**_______________ **JURISDICTION:**_______________	**DATE:** ___/_____/___	**ASSESSED BY:**

NAME: ______________________________
ADDRESS: ______________________________
PHOTO IDs: ______________________________
HANDHELD/ GPS ID:

SECTION 1- BACKGROUND INFORMATION (GIS)

BMP TYPE :

- ☐ Water Quality Dry Pond
- ☐ Unspecified Dry Pond
- ☐ Wet Pond
- ☐ Wetland
- ☐ Filter (specify: ______________)
- ☐ Infiltration (specify:____________)
- ☐ Dry Swale
- ☐ Wet Swale
- ☐ Grass Channel
- ☐ Dry Well
- ☐ Permeable Pavement
- ☐ Bioretention
- ☐ Level Spreader
- ☐ WQ Inlet
- ☐ Underground
- ☐ Proprietary Device
- ☐ Other ______________

YEAR CONSTRUCTED: __________

OWNERSHIP
☐ Public ☐ Private ☐ Unknown

SITE CHARACTERIZATION

DRAINAGE AREA: _____(acres) **IMPERVIOUS COVER:** _____(%) Discerned from: ☐ Plan ☐ County Data ☐ GIS ☐ Field

CONTRIBUTING DRAINAGE AREA (% land use): *Note – All percentages should sum up to 100%.*

_____Industrial _____Commercial _____Urban/Residential _____Suburban/Res
_____Forested _____Institutional _____Golf course _____Park
_____Crop _____Pasture _____Other: __________

CALCULATED WATER QUALITY VOL: _____(ft^3)

SECTION 2- FIELD VISIT

Rain in last 48 hrs? ☐ Yes ☐ No

Evidence of high water table? ☐ Yes ☐ No

DESIGN ELEMENTS

FACILITY SIZE:
Length: _____(ft)
Width: _____(ft)
Surface Area: _____(ft^2)
Depth of WQ storage _____(ft)

OBSERVED WQ STORAGE VOL:
_____(ft^3)

HYDRAULIC CONFIGURATION
☐ On-line Facility
☐ Off-line Facility

DESIGN STORM:
☐ Water Quality
☐ Flood Control
☐ Channel Protection
☐ Unknown

SIGNAGE (check all that apply)
☐ None ☐ Flood Warning ☐ Stormwater Education ☐ No Trespassing ☐ Wildlife Habitat
☐ Public Property ☐ Do Not Mow ☐ Other: ______________________

OUTLET CHARACTERISTICS

MEASUREMENTS:
Number of Outlets : __________
Outlet Diameter: __________(in)
(up to 4 outlets) __________(in)
__________(in)
__________(in)
Outlet includes restrictor? ☐ Yes ☐ No

TYPE OF OUTLET: ☐ N/A ☐ Pipe ☐ Riser ☐ Weir ☐ Large Storm Overflow ☐ Open channel ☐ Large Storm By-pass ☐ Other: __________

OUTLET FEATURES: ☐ Other________ ______________
☐ N/A ☐ Trash Rack ☐ Pond Drain ☐ Inverted outlet pipe
☐ Hooded outlet ☐ Multiple outlet levels ☐ Anti-vortex device
☐ Perforated pipe ☐ Gravel Diaphragm ☐ Micropool

☐Impoundment BMP
BMP contains Emergency Spillway?: ☐ Yes ☐ No
If yes, type: ☐ Channel ☐ Riser Overflow
☐ Weir ☐ Other: __________

OUTLET CONDITIONS:

Outlet Erosion	☐None	☐Slight	☐Moderate	☐Severe
Outlet Clogging	☐None	☐Slight	☐Moderate	☐Severe
Structural Problems	☐None	☐Slight	☐Moderate	☐Severe

DOWNSTREAM CONDITIONS: ☐Unknown ☐ Stream ☐ Other
☐ Closed storm sewer ☐ Surface channel ☐ Road ditch

Active Erosion	☐None	☐Slight	☐Moderate	☐Severe
Trash	☐None	☐Slight	☐Moderate	☐Severe
Sedimentation	☐None	☐Slight	☐Moderate	☐Severe
Odor	☐None	☐Slight	☐Moderate	☐Severe
Algae	☐None	☐Slight	☐Moderate	☐Severe
Other WQ Problems	☐None	☐Slight	☐Moderate	☐Severe

SOIL OR FILTER MEDIA

TYPE OF FILTER MEDIA
☐ N/A ☐ Unknown ☐ Soil Media ☐ Sand ☐ Gravel ☐ Large Stone ☐ Organic material ☐ Other__________
Depth of filter media __________(in)
Avg. depth of sediment build-up?______(in)

SOIL MEDIA SAMPLE: *Note – Complete during site investigation, if applicable*
Dominant Soil Type ☐ Clay ☐ Loam ☐ Sand Is the soil homogenous ☐ Yes ☐ No

Comments:

VEGETATION

GENERAL OBSERVATIONS:
☐ Landscaped
☐ Aquatic Bench
☐ Invasive Species
☐ Plant Diversity

TYPE OF GOUND COVER (% of Surface Area in Plan View up to low Outlet)**:**
Note – All percentages should sum up to 100 %.
_____Trees _____Grasses/Perennials _____ Ponded water
_____ Managed Turf _____ Bare Soil _____Shrubs
_____ Gravel/stone _____ Mulch _____ Other: ___________

Type of mulch, if present: ☐ Hardwood ☐ Pine Straw ☐ Other__________
Rate degree of shading of BMP Surface Area: ☐ Well Shaded ☐ Some Shading ☐ No Shading

INLET CHARACTERISTICS

MEASUREMENTS:
Number of Inlets : __________
Inlet Diameter/Width __________(in)
(up to 4 inlets) __________(in)
__________(in)
__________(in)

TYPE OF INLET: (check all that apply)
☐ Open Channel ☐ Closed Pipe
☐ Sheet Flow ☐ Curb Cut
☐ Other: __________

INLET SUBMERSION:
☐ Complete
☐ Partial
☐ None

INLET CONDITIONS:
Inlet Erosion ☐None ☐Slight ☐Moderate ☐Severe
Inlet Clogging ☐None ☐Slight ☐Moderate ☐Severe
Structural Problems ☐None ☐Slight ☐Moderate ☐Severe

Does BMP receive additional overland flow?
☐ Yes ☐ No

PRETREATMENT

TYPE OF PRETREATMENT
☐ None
☐ Sediment Forebay (_____ ft^3)
☐ Grass Channel
☐ Riprap Channel or Apron
☐ Gravel Filter Strip
☐ Grass Filter Strip
☐ Plunge Pool?
☐ Stone Diaphragm
☐ *Other:* __________

PRETREATMENT FUNCTION
Is pretreatment functioning? ☐ Yes ☐ No
Is sediment removal necessary? ☐ Yes ☐ No
Signs of pretreatment bypass? ☐ Yes ☐ No
Signs of flow of sediment from pretreatment to BMP? ☐ Yes ☐ No
Severity: ☐ Slight ☐Moderate ☐Severe

GENERAL DESIGN

BMP FEATURES (check all that apply)
☐ Maintenance Access
☐ Fence
☐ Multi-cell
☐ Micropool
☐ Impermeable Liner
☐ Underdrain
☐ Clean Out
☐ Observation Well
Is water present in observation well?
☐ Yes ☐ No Depth: _____ ft
☐ Pond Drain
☐ Large Storm Overflow
☐ Large Storm Bypass
☐ Other:_______________

CONVEYANCE SYSTEM THROUGH BMP
☐ Low Flow Channel
☐ Concrete ☐ Eroded ☐ Earthen ☐ Other ____________
☐ No Defined Channel
Length of Shortest Flow Path: __________(ft)

Is BMP designed with a Permanent Pool? ☐ Yes ☐ No
Permanent Pool Max Depth: __________(ft)
Permanent Pool Avg. Depth: __________(ft)
Permanent Pool Volume: __________(ft^3)

PERFORMANCE

GENERAL PROBLEMS: (check all that apply)

- ☐ Maintenance Needed
- ☐ Water Bypass of Inlet
- ☐ Water Bypass of Outlet
- ☐ Incorrect Flow Paths
- ☐ Short-circuiting of treatment mechanism
- ☐ No or ineffective treatment
- ☐ No or ineffective pretreatment
- ☐ Others ________________________ __
- ☐ Erosion at Embankments
- ☐ Erosion within Facility
- ☐ Deposition within Facility
- ☐ Inappropriate Ponding of Water
- ☐ Clogged Pond Drain/Underdrain
- ☐ Clogged Media
- ☐ Inappropriate media material
- ☐ Inappropriate underlying soil (infiltration)
- ☐ Permanent Pools not stable
- ☐ Inadequate vegetation
- ☐ Dead or Diseased Vegetation
- ☐ Too much vegetation/invasives
- ☐ Trees on Embankment
- ☐ Failing structural components
- ☐ Safety issue (Note:________________)

WATER QUALITY IN FACILITY: ☐N/A

Algae	☐None	☐Slight	☐Moderate	☐Severe
Odor	☐None	☐Slight	☐Moderate	☐Severe
Color	☐None	☐Slight	☐Moderate	☐Severe
Turbidity	☐None	☐Slight	☐Moderate	☐Severe

EVIDENCE OF:

- ☐ Geese
- ☐ Animal Burrows
- ☐ Mosquitoes

PROBLEM		1=NONE	2 - FEW	3 – SEVERAL	4-SEVERE
TRASH		No evidence of trash	A few pieces of trash throughout BMP	Trash accumulation near inlet/outlet	Lots of trash in BMP or BMP used for storage
BMP BANK EROSION		No noticeable erosion	Slight erosion < 5% of bank affected	Moderate erosion ~15% of bank affected	Banks severely eroded, >25% of bank affected
SEDIMENT DEPOSITION		No sediment deposition	Areas of minor sediment deposition	Areas of some deposition, may be severe near inlet/outlets	Lots of deposition resulting in pond bottom clogging
SURFACE SLOPE		0-1% BMP surface slope	1-3% BMP surface slope or steeper slopes with check dams,	3-5% BMP surface slope with no check dams,	>5% surface slope;
SIDE SLOPES		BMP side slopes 3:1 or flatter	BMP side slopes 2:1	Steep BMP side slopes	Risk of side slope failure
STRUCTURAL		No evidence of structural damage	Minor problems – bank slump, eroded channels	Moderate structural problems –failure pending	Structural failures – bank failure, blowout
VISIBILITY		High visibility, near high-traffic areas	Some visibility, near traffic areas	Limited visibility, near low traffic areas	No visibility, behind buildings or fences
VEG COVER		No mowing in/around BMP	Mowing along BMP edges but areas of no mow in BMP bottom	Mowed turf vegetation	BMP bottom has large areas of bare soil
		Dense plant cover (>50%)	Plant cover 30-50%	Some plant cover 15-30%	Sparse vegetative cover (<15%),
VEG HEALTH	TREES	Healthy and established	New growth	Stressed	Dead
	GROUND COVER	Healthy and established	New growth	Stressed	Dead
	SHRUBS	Healthy and established	New growth	Stressed	Dead

OVERALL PERFORMANCE SCORE (circle one number)

Excellent design and function, no general problems with performance	BMP is well designed, but is undersized or has a few performance problems	BMP is adequately designed, several problems with performance are noted	Poor BMP design, severe performance problems or failure
10 9 8	7 6 5	4 3	2 1

FIELD NOTES

GOOD OR INTERESTING DESIGN FEATURES:
PHOTO #'S:

POOR OR PROBLEMATIC DESIGN FEATURES:
PHOTO #'S:

SECTION 3 – DESIGN PLAN VERIFICATION

AS BUILT (OR DESIGN) PLAN AVAILABLE: ☐ Yes ☐ No
Do field observations match design plans/as-builts? Describe any differences.

Soil type in facility ☐ Yes ☐ No If no, describe:

Pretreatment type and size ☐ Yes ☐ No If no, describe:

Signage ☐ Yes ☐ No If no, describe:

Low-flow channel ☐ Yes ☐ No If no, describe:

Dimensions/volume ☐ Yes ☐ No If no, describe:

Inlet type, #, and sizing ☐ Yes ☐ No If no, describe:

Outlet type, #, and sizing ☐ Yes ☐ No If no, describe:

Vegetation composition ☐ Yes ☐ No If no, describe:

Other features ☐ Yes ☐ No If no, describe: