National Pollutant Discharge Elimination System
Phase I MS4 Permit No. 99-DP-3313 MD0068276

Permit Term October 2005 to October 2010

Fourth Annual Report
October 21, 2009

Submitted to:
Water Management Administration
Maryland Department of the Environment
1800 Washington Boulevard
Baltimore, MD 21230

Submitted by:
Highway Hydraulics Division
Maryland State Highway Administration
707 North Calvert Street, C-201
Baltimore, MD 21202

SHA
State Highway Administration
Maryland Department of Transportation

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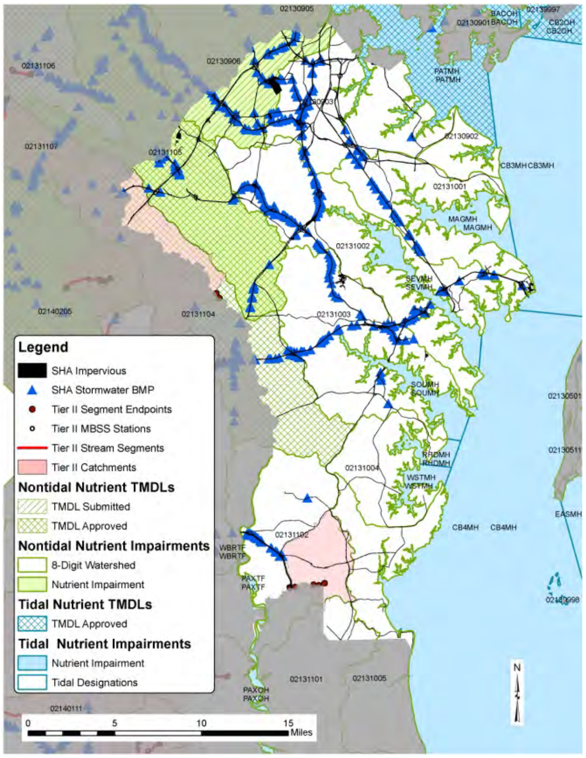
Executive Summary



Anne Arundel County Map with SHA Impervious & BMPs Overlaid on Tier II Waters and Nutrient Impairments

The Maryland State Highway Administration (SHA) is submitting this fourth annual report and permit re-application for the NPDES Phase I Municipal Separate Storm Sewer System (MS4) permit that was issued in October 2005 by the Maryland Department of the Environment (MDE) Water Management Administration (WMA). This annual report covers the time period October 2008 to September 2009. A summary of the permit conditions and our work toward meeting them is provided below as a general overview of SHA permit activities for this report period.

This report also serves as SHA re-application for the next term of the NPDES Phase I permit. Evaluation of the current permit and recommended improvements are included as part of this re-application.

Due to budget cutbacks, some of the programs have been adjusted through scheduling delays or projects placed on hold. This has not affected our commitment and ability to meet the requirements of this permit.

Source Identification

Source identification efforts were completed as reported in the 2008 annual report. Work continues on our NPDES GIS viewer tool that will enable all users to access the data. With the completion of the Prince George's county impervious layer, included in this report, the impervious accounting condition has been completed for the nine Phase I counties. Updates to the layers will be completed every 5 years or when new ortho-photography is developed statewide.

Discharge Characterization

We continue to investigate and research topics in order to maximize water quality in our construction methods, permanent stormwater runoff controls, decisions in design, and location of roadways and maintenance techniques. The grass swale study is nearing completion and we anticipate the final report in December 2009. This study seeks to evaluate the affects of native grass check dams on pollutant removal. Two new studies have also been initiated. One seeks to optimize our bioretention soil media and the second seeks to evaluate function of infiltration facilities that have transitioned to wetlands in terms of quality and quantity stormwater treatment. We have also added two resources on pollutant load reductions to our list of references.

Management Program

Our program continues to effectively incorporate the many permit components. While we have kept our sights on the development of the new environmental site design (ESD) regulations, we have continued to measure our performance in the areas of erosion and sediment control during construction, illicit discharge detection and our internal business goal of maximizing the number of functionally adequate stormwater facilities statewide.

The ESC Program developed and implemented the ESC Quality Assurance Toolkit (QA Toolkit). This tool allows field inspectors to enter inspection results directly into a field compute that is connected to the general ESC inspection database through the internet. This improves efficiency, accuracy of data entry and reporting.

SHA is also seeking to improve the consistency of illicit discharge elimination with the development and of improved illicit discharge elimination procedures for following up on the elimination. These procedures will be implemented in November 2009.

Many of our environmental stewardship and training programs were augmented with two new initiatives. The initiatives include an SHA *Vehicle and Equipment Idling Policy* that seeks to reduce fuel consumption and the *One Million Tree Initiative*. SHA has partnered with MD DNR, FHWA and the Maryland Department of Safety and Correctional Services to plant a million trees in Maryland as part of Governor O'Malley's *Smart, Green and Growing* initiative.

The Design Build Operate and Maintain (DBOM) pilot to place the operations and maintenance responsibilities for permanent stormwater management facilities with a private company continues. The contract was successfully bid and let. The design/build team is gearing up for a five-year commitment to guarantee the functioning and maintenance of stormwater facilities in Charles County.

Watershed Assessment

Coordination with local NPDES jurisdictions continues. We are also moving forward with watershed restoration sites within the Patuxent River Watershed. With the EPA Green Highway grant, SHA is in the process of developing an implementation framework for watershed-based stormwater design within SHA which could be applicable to any transportation agency.

Watershed Restoration

SHA has added to the restoration projects in increased the number to 105. As we determined that MDE is interested in our maximizing this effort, we have included many past restoration projects that have already been constructed and several new projects. Our acreage for watershed restoration has increased to 671 acres of impervious surfaces treated by retrofit projects that include upgrading stormwater facilities and stream stabilization or restoration efforts. We will continue to maximize these efforts in the future as funding allows.

Assessment of Controls

The Long Draught Branch stream restoration project has been resurrected but with delayed funding until 2014. We will continue the project with the post-construction monitoring when the project is completed. The *Wet Infiltration Basin Transitional Performance Study* will augment data on assessment of controls.

Program Funding

Our NPDES program remains fully funded.

Total Maximum Daily Loads

By remaining in compliance with this permit, SHA is controlling stormwater pollution to the maximum extent practicable. Development of the TMDL implementation strategy to address inclusion of pollutant loadings and waste load reductions into future permit requirements continues. Coordination with the Science Services Administration during the last year resulted in sharing of data and on-going cooperation between our two agencies.

Table of Contents

Executive Summary i
Table of Contents iii
List of Figures iv
List of Tables v

Part 1 Standard Permit Conditions and Responses 1-1
A Administration of Permit 1-3
B Legal Authority 1-3
C Source Identification 1-4
D Discharge Characterization 1-13
E Management Program 1-17
F Watershed Assessment 1-41
G Watershed Restoration 1-43
H Assessment of Controls 1-49
I Program Funding 1-50
J Total Maximum Daily Loads 1-50

Part 2 NPDES MS4 Phase I Permit Re-Application 2-1

Part 3 Stormwater Management Facility Program Status 3-1
3.1 Introduction 3-1
3.2 Inventory and Inspection 3-1
3.3 Maintenance and Remediation 3-9
3.4 Other Topics 3-18
3.5 Summary 3-20

Appendix A Examples of Source Identification A-1
Appendix B Examples of Impervious Layers B-1
Appendix C Progress Report: Field Evaluation of Water Quality Benefits of Grass Swale for Managing Highway Runoff C-1
Appendix D Progress Report: Field Evaluation of Wet Infiltration Basin Transitional Performance D-1
Appendix E Progress Report: Nutrient Removal Optimization of Bioretention Soil Media E-1
Appendix F Illicit Discharge Elimination Process F-1
Appendix G TMDL Mapping with SHA Impervious & SWM BMPs: Nutrients & Sediments G-1

CD Report PDF Files, MDE Attachment A Databases, SHA Geodatabases

List of Figures

Figure **Page Number**

1-1 Organizational Chart for NPDES Permit Administration.. 1-2
1-2 ArcMap Session Using SHA Hydraulic Asset Geodatabase 1-5
1-3 Example of Impervious Layer 1-10
1-4 Data Fields in Impervious Layer Geodatabase 1-10
1-5 SHA-Owned Impervious Surface Treatment in 9 NPDES Counties...................... 1-13
1-6 Native Grass Check Dams at Study Swale 1-14
1-7 Rooting Depths of Various Native Grasses Compared to Kentucky Bluegrass 1-14
1-8 ESC Quality Assurance for FY 2009, Fourth Quarter... 1-20
1-9 Screen Shot of ESC QU Toolkit 1-22
1-10 Information Board on ESC QA Toolkit.. 1-23
1-11 Carroll County GIS – Sediment 1-51
1-12 Carroll County GIS – Nutrients 1-51
1-13 Tier II Streams with Nutrient Impairments in Carroll County 1-52
1-14 Detail of Little Morgan Run – Tier Ii Segments.. 1-52
1-15 Patuxent River Watershed with NPDES Counties... 1-54
1-11 SHA Roadways Functional Classifications by NPDES County............................ 1-56

3-1 Stormwater Management Facilities Inspection and Remediation Program.............. 3-8
3-2 BMP 020186 – removal of Sediment from Infiltration Trench 3-10
3-3 BMP 130292 – Inflow Channel Stabilization During Construction....................... 3-10
3-4 BMP 130007 – Inflow Channel Stabilization After Construction.......................... 3-10
3-5 Excavation of Infiltration Trench 020191... 3-11
3-6 Infiltration Trench 020193 In-Kind Replacement 3-12
3-7 Infiltration Trench 210013 In-Kind Replacement 3-12
3-8 Reconstruction of Failed Infiltration Basin to Sand Filter at MD 32 (020121)....... 3-14
3-9 Functional Enhancement of Infiltration Basin at MD 100 to Shallow Marsh (020120).. 3-14
3-10 Reconstruction of Infiltratiuon Basin at MD 32 to Pocket Pond (020029) 3-15
3-11 Reconstruction of Failed Infiltration Basin at MD 100 to Sand Filter (020122)..... 3-16
3-12 Reconstruction of Failed Infiltration Basin at MD 100 to Micro-Pool ED Pond (020111).. 3-17
3-13 Failed Bioretention at SHA Glen Burnie Maintenance Shop 3-18
3-14 GPS and Field Tool Used for Efficient Data Entry During Inspections.................. 3-18
3-15 iMap Screen Captures... 3-19
3-16 SWM Inspection Workshop (September 2009)... 3-20
3-17 Progress in SWM Facilities Program.. 3-20

List of Tables

Table		Page Number
1-1	NPDES GIS Viewer Development Progress	1-6
1-2	Source Identification Update Schedule	1-7
1-3	Meta-Data for Impervious Layers	1-11
1-4	Right-of-Way (ROW) Layer Meta-Data	1-11
1-5	SHA Impervious Accounting	1-12
1-6	ESC Training Held by SHA (10/2008 to 9/2009)	1-24
1-7	Winter Materials Used by SHA	1-27
1-8	Industrial NPDES Permit Status	1-29
1-9	Capital Expenditures for Pollution Prevention BMPs	1-29
1-10	Illicit Discharge Screenings	1-31
1-11	Adopt-A-Highway Program	1-35
1-12	Sponsor-A-Highway Program	1-35
1-13	Partnership Planting Program	1-35
1-14	Pesticide Applicator Training (ENV100)	1-39
1-15	SHA Vegetation Management (Re-Certification Conference (ENV200)	1-39
1-16	Pesticide Core and Right-of-Way Pre-Certification (ENV210)	1-39
1-17	Pesticide Aquatic Certification (ENV600)	1-39
1-18	Watershed Restoration Projects	1-44
1-19	Capital Expenditures for NPDES at SHA	1-50
2-1	Illicit Discharge Screenings to Date	2-1
3-1	Current Statewide SWM Facilities	3-2
3-2	SWM Facilities Remedial Ratings Summary by County	3-3
3-3	Minor Maintenance Summary	3-9
3-4	BMP Major Maintenance Summary	3-11
3-5	BMP Enhancement and SWM Remedial Projects Summary	3-13

PART ONE

Standard Permit Conditions and Responses

Introduction

The Maryland State Highway Administration (SHA) is committed to continuing our National Pollutant Discharge Elimination System (NPDES) Program efforts and is pleased to partner with the Maryland Department of the Environment (MDE), the Environmental Protection Agency (EPA) and other NPDES jurisdictions in order to achieve the program goals.

The original NPDES phase one permit guided SHA through establishing our NPDES program. (The permit, MS-SH-99-011, was issued on January 8, 1999 and expired in 2004.) The current permit (99-DP-3313, MD0068276, issued October 2005) focuses on improving water quality benefits and developing a watershed-based outlook for stormwater management and NPDES program elements.

Comments dated September 28, 2009 were received from MDE relating to a review of our 2007 and 2008 reports. Responses to these comments and methods of adjustment for our current program to implement the requested changes in the comments are addressed in this Part One under the related permit conditions.

This is the fourth annual report for the re-issued permit and this report also serves as the permit re-application. The current permit will expire next year, October 21, 2010. There are four areas that the permit requires (see Part IV.C) be addressed at a minimum in the re-application:

1. *SHA NPDES Stormwater Program Goals;*
2. *Program Summaries for the Permit Term regarding:*
    a. *Illicit Discharge Detection and Elimination (IDDE) results;*
    b. *Watershed Restoration status including SHA totals for impervious acres, impervious acres controlled by stormwater management, and the current status of watershed restoration projects and acres managed;*
    c. *Pollutant load reductions as a result of this permit;*
    d. *Other relevant data and information for describing SHA programs;*
3. *Program Operation and Capital improvements costs for the permit term;*
4. *Descriptions of any proposed permit condition changes based on analyses of the successes and failures of the SHA efforts to comply with conditions of this permit.*

We have addressed each of these components for the re-application throughout Part One of the report.

In addition to addressing the re-application components, Part One of the report also lists the permit conditions and explains SHA activities over the last year in compliance with each condition. Wherever possible, future activities and schedules for completion are provided. In depth discussions for some of the major program components follow this section.

Part Two of this report is the formal re-application. Part Three discusses the SHA Stormwater Facility Program in depth. A number of appendices are included at the end of the report that contain research reports, examples of data and other detailed information. A CD is also included that contains portable document format (PDF) files of the entire report and appendices as well as delivery of the required databases listed in Attachment A of the permit, our NPDES hydraulic asset geodatabase that includes all our stormdrain information and our NPDES impervious accounting geodatabase that includes the SHA impervious features.

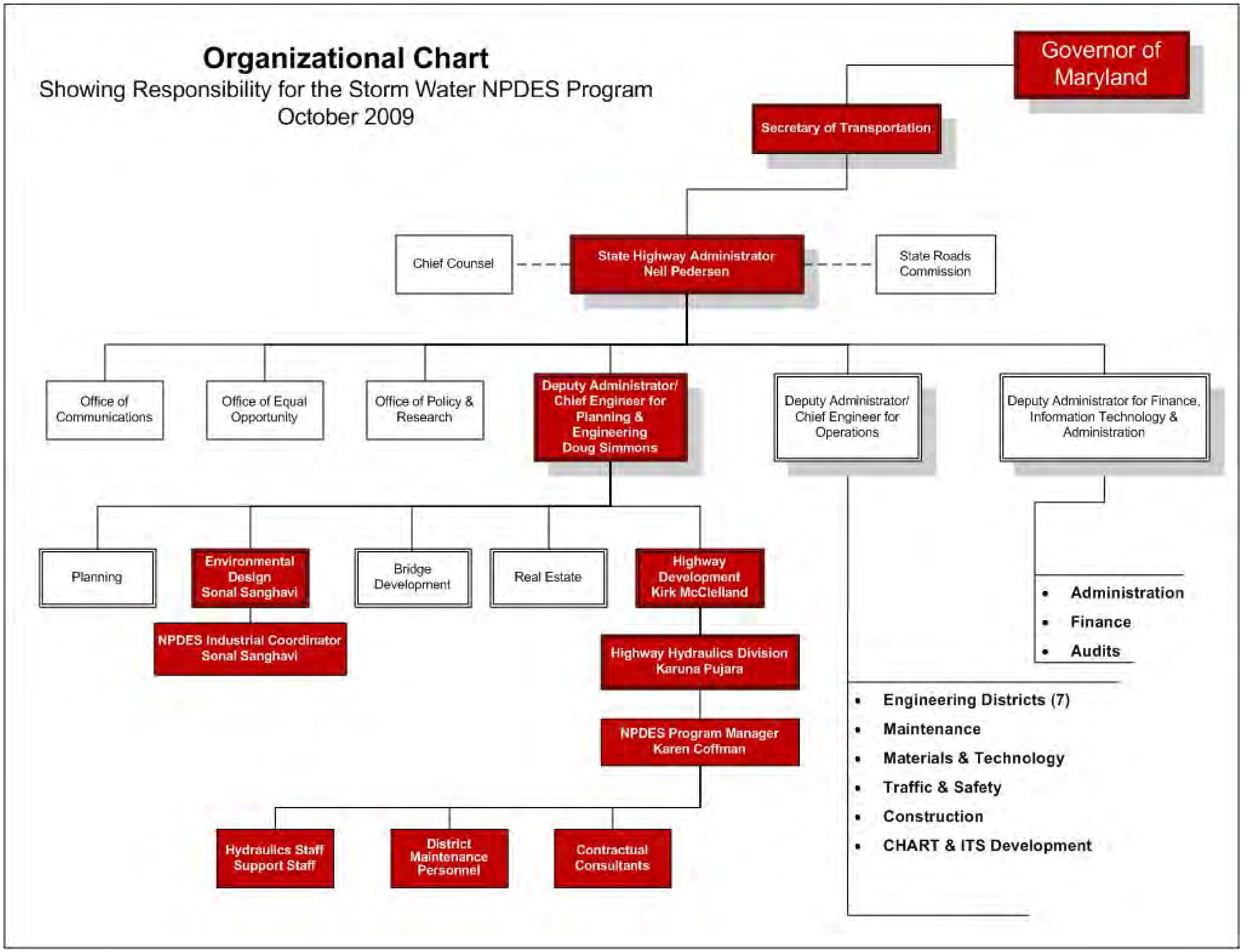


Figure 1-1 Organizational Chart for NPDES Permit Administration

A Administration of Permit

Administration responsibilities of the NPDES MS4 permit for SHA is listed below and an organizational chart is attached as Figure 1-1.

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B Legal Authority

A description of the legal authority maintained by SHA was restated in the first annual report dated October 21, 2006.

The following statement of legal authority was developed by the Assistant Attorney General and submitted with our original permit application for the 1999 permit.

"The applicant can operate pursuant to legal authority established by statute, ordinance or series of contracts, which authorizes or enables the applicant at a minimum to:

> *"(A) Control through ordinance, permit, contract, order or similar means, the contribution of pollutants to the municipal storm sewer by storm water discharges associated with industrial activity and the quality of storm water discharged from sites of industrial activity:*
>
> *"The only legal manner in which a person may discharge or increase storm water runoff/volume into SHA's Municipal Storm Water Management System is by connection via access control permit issued in accordance with COMAR 11.04.05.06.C and D (commercial access) and 11.04.06.02.G (residential access). SHA assures that these permits limit volume and quality of stormwater input from adjacent properties. In addition, with respect to storm water runoff as a result of construction activity on state highways, SHA may, through contract, impose restrictions within the contract documents and , if violations with respect to storm water discharge is discovered, SHA may issue a stop work order which required the contractor and/or its subcontractors to cease and desist until the violations are corrected.*

"(B) Prohibit through ordinance, order or similar means; illicit discharges to the municipal separate storm sewer:

"SHA does not enact ordinances per se, but may terminate or suspend a commercial or residential access permit as discussed above if a permit condition is violated or, as appropriate, may sue for injunctive relief to assure compliance in accordance with Maryland Transportation Code Annotated Section 8-625 (b). In the event the illicit discharge is caused by its contractor under a construction or maintenance project on a state highway, the procurement officer may issue a stop work order as discussed above which is an administrative order. The illicit discharges by persons other than permit holders or contractors (i.e., vehicles or pedestrians using the highway system) are prohibited by Md. Environ. Code Ann. §4-410-413; and Md. Transp. Code Ann. §21-1111(d) (dumping trash and oil into the storm sewer).

"(C) Control through ordinance, order or similar means the discharge to a municipal separate storm sewer of spills, dumping or disposal of materials other than storm water:

"These concerns are covered in the previous paragraph.

"(D) Control through interagency agreements among co-applicants the contribution of pollutants from one portion of the municipal system to another portion of the municipal system:

"The State Highway Administration occasionally enters into memoranda of agreement with other agencies, counties and/or municipalities and would, by

contract, provide for the coordination required by this subparagraph.

"(E) Require compliance with conditions in ordinances, permits, contracts or orders:

"As discussed above, SHA may require compliance with conditions in its permit and contracts by suspending privileges thereunder or issuing stop work or other appropriate orders in order to obtain compliance. Additionally, SHA may resort to legal action in the courts to enforce compliance.

"(F) Carry out all inspection, surveillance and monitoring procedures necessary to determine compliance and noncompliance with permit conditions including the prohibition on illicit discharges to the municipal separate storm sewer:

"Compliance with permit conditions are determined routinely by inspections by SHA employees or consultants. Ordinarily, the permits issued are for construction of road access on to a state highway, which roads are subsequently dedicated to a public entity (i.e., a county dedication) or are part of a parking area open to the public. To our knowledge, there are no properties or developments for which permits are issued that are of such a nature as to prohibit subsequent inspection by state highway personnel."

C Source Identification

Source identification deals with identifying sources of pollutants and linking those sources to specific water quality impacts on a highway district basis. Source identification is also tied to impervious surfaces and land uses.

For this permit term, MDE has defined the source identification effort as completing the description of the SHA storm drain and BMP system, submitting BMP data to MDE and creating an impervious surface account.

Maryland SHA has successfully completed the GIS development of SHA storm drain systems within the nine Phase I MS4 counties. The geodatabase containing all our hydraulic assets within theses counties as well as inspection data for stormwater management facilities and outfalls is included on the attached CD. Our source identification effort is now focused on periodically updating our geodatabase.

SHA is continuing to pursue evaluating our impact on waterways in terms of roadway functional classification and traffic volumes. We are also actively pursuing ways to predict our pollutant loadings.

C.1 Describe Storm Drain System

Requirements under this condition include:

a) *Complete Source identification requirements by October 21, 2009;*
b) *Address source identification data compatibility issues with each jurisdiction where data are collected. Data shall be organized and stored in formats compatible for use by all governmental entities involved;*
c) *Continually update its source identification data for new projects and from data gathered during routine inspection and repair of its municipal separate storm sewer system; and*
d) *Submit an example of source identification for each jurisdiction where source identification is being compiled.*

C.1.a Complete Source Identification

SHA completed the identification and GIS development for our storm drain systems and stormwater management facilities in 2008, well before the October 21, 2009 deadline. Our focus has shifted to updating our source identification information for all nine counties. Information on source identification updates is included under section C.1.c, Update Source ID Data.

C.1.b Data Compatibility

SHA continues to provide data to the other NPDES jurisdictions as well as acquire data from them. The NPDES data generated by SHA is in standard ESRI Geodatabase format and is either natively compatible with other jurisdictions, or can be exported to ESRI shape file format.

Geospatial Database Development

SHA has developed a geospatial database for our source identification and inspection data. This database will be expanded to include other components of the program as they are brought together and as we update our standard procedures and inspection manuals. The geospatial database is deployed using the ESRI Geodatabase data format in an ArcSDE enterprise environment. All of the SHA NPDES data including source identification, BMP inspections, outfall screening, outfall inspections, and impervious area are currently housed in the database. See Figure 1-2 for an example of data displayed in ArcMap.

Updates to the data continue to be performed on a county or district wide basis. The data management and update process is performed using ESRI technology and custom developed applications specific to the SHA data model. SHA has focused on developing a simple data management architecture that allows for the checking out of versioned databases to NPDES team members for updates. The versioned database can be either edited by a custom office editing application, or, deployed to the field with a custom field editing application.

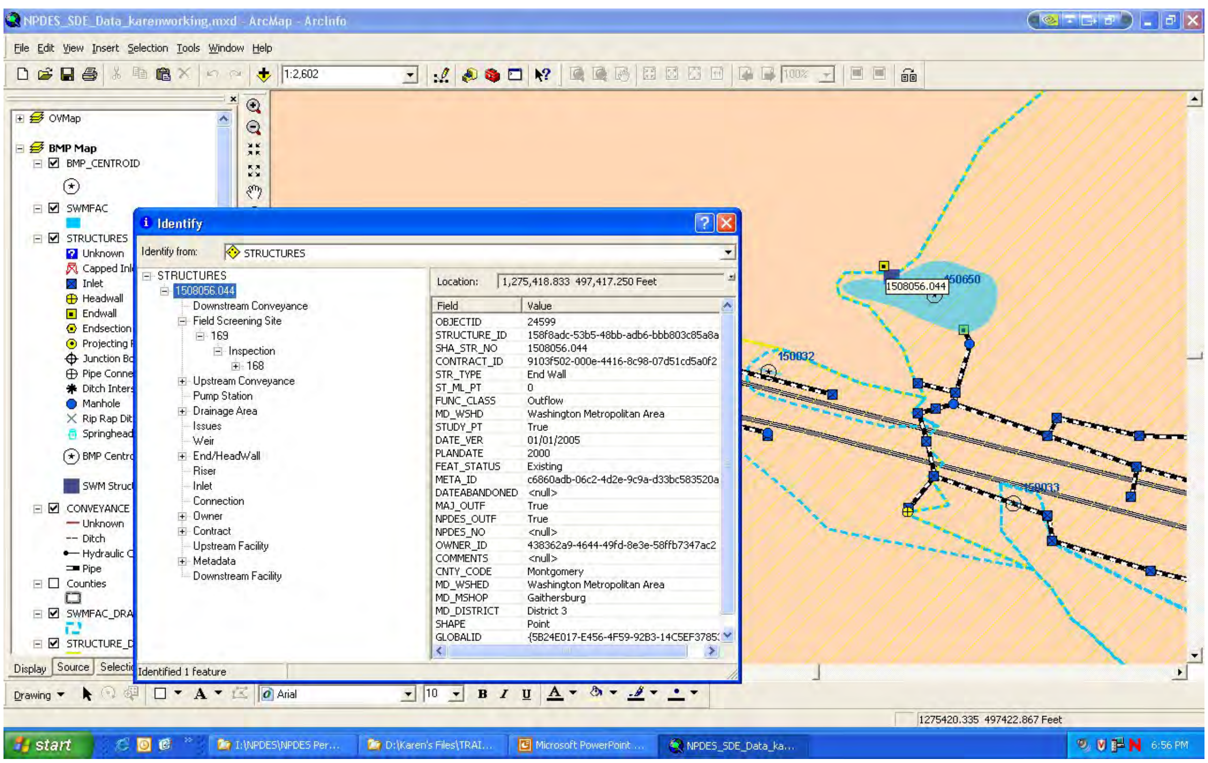


Figure 1-2 ArcMap Session Using SHA Hydraulic Asset Geodatabase

NPDES GIS Viewer Application

The SHA NPDES GIS viewer application tool has been developed. The intent of the tool is to utilize the power of the enterprise GIS server to allow SHA to provide general access to the geodatabase information. While the tool platform is complete, many of the modules are currently undergoing final development. Table 1-1 lists percent complete for each module.

- <u>SHA NPDES Viewer</u> – web-based application that will allow SHA personnel, NPDES jurisdictions and other users to access our data. The viewer application will allow SHA staff to view, analyze, and query the storm drain, cross culvert and stormwater facility data. Access to the viewer from outside jurisdictions may not be immediately available as we work through firewall issues.

- Stormwater Facility Program Module – facilitates the management of the BMP inspections, maintenance, remediation or enhancement. Stormwater retrofits that upgrade facilities that were constructed prior to the 2000 Maryland Stormwater Design Manual are also included in the NPDES restoration credits.
- BMP Numbering Module – facilitates generating and maintaining unique BMP numbers in a secure, automated manner. Unique BMP numbers are generated individually or in pre-defined blocks of numbers, depending on the end-users needs.
- IDDE Module – allows tracking of NPDES outfall screening, illicit discharges, reporting and elimination efforts.
- Water Quality Bank/ Impervious Accounting Module – tracks impervious areas treated by structural stomwater BMPs for both the SHA/MDE water quality bank and for NPDES restoration credit. This module currently only tracks the SHA/MDE water quality bank balances.
- Outfall & Storm Drain Inspection & Remediation (SOIRP) Program Module – facilitates the management of the storm drain and outfall inspection data, maintenance, remediation or enhancements. Many of the remediation efforts undertaken here are also NPDES restoration projects.

Table 1-1 NPDES GIS Viewer Development Progress

Phase of Development	% Complete
NPDES GIS Viewer Platform	90
SWM Program Module	60
BMP Numbering Module	90
IDDE Module	0
WQ Bank/Imp. Accounting Module	30
Outfall Program Module	0

GIS Standard Procedures Manual

We are continuing to develop our standard procedures which document data collection, inspection and data management standards for our NPDES data. The outline for the standard procedures is as follows:

Chapter 1: Introduction
Chapter 2: Source Identification & Inventory
Chapter 3: BMP Field Inspections & Data Collection Procedures
Chapter 4: Storm Drain & Outfall Inspection Procedures
Chapter 5: Illicit Discharge, Detection & Elimination Procedures
Chapter 6: Data Management
Chapter 7: BMP Assessment Guidelines for Maintenance & Remediation

Efforts to finalize the standard procedures continue and our goal is to publish a complete document this coming year. The final two chapters, data management standards and BMP remediation standards are currently being finalized.

GIS Development Workshops

Due to budget cuts, we reduced our workshop schedule for the past year to one workshop offered on September 15 and 16, 2009. This was an inspection workshop.

Budget constraints have led to the realization that on-line training is a good way to keep inspectors and GIS developers current on our standards, while at the same time, reducing costs. We will begin efforts to develop on-line training for all our GIS development standards in the next year. These self-training tools will enable the field and office personnel to view training material on their own without the need for formal workshops. Certification requirements are also being considered.

The training modules include:

- Source ID procedures
- IDDE Field training
- Outfall stability inspection
- BMP inspection
- GIS Data Management.

Table 1-2. Source ID Update Schedule

County	Source ID Complete	1st Update	2nd Update
Howard	**01/2001-C**	**01/2005-C**	**7/2009-I**
Montgomery	**01/2001-C**	**09/2006-C**	*7/2010*
Anne Arundel	**08/2003-C**	**8/2008-I**	
Prince George's	**03/2003-C**	**9/2008-I**	
Baltimore	**03/2004-C**	**7/2009-I**	
Harford	**08/2005-C**	*7/2010*	
Frederick	**09/2006-C**	*7/2010*	
Carroll	**05/2008-C**	*4/2011*	
Charles	**06/2008-C**	*4/2011*	

Note: **Bold text** is actual completion dates (-**C**) or actual initiation dates (-**I**).
Italicized text is projected initiation dates.

C.1.c Update Source Identification Data

Since the initial source identification is complete for all the NPDES MS4 Phase I counties, the permit activity for this condition will focus on updating the source data.

Typically, source identification updates are performed on completed counties every three years or once the maintenance and remediation efforts are complete. However, budget cuts over the last year have caused us to delay updates that were programmed to be initiated FY 09 and to reduce the update efforts for Baltimore and Howard counties. The update efforts are confined to identifying and inventorying new storm drain that is associated with stormwater facilities (rather then all new roadway projects), inspecting only new BMPs and screening 150 outfalls per county for illicit discharges.

Future updates will be performed according to Table 1-2. The following county database updates are in progress:

- Prince George's,
- Anne Arundel,
- Baltimore, and
- Howard.

Information for each county is listed below in the order in which the original source identification efforts were completed:

Howard County – The inventory, database and GIS model of drainage features were completed in January 2001. Updates to the database and GIS model were completed in January 2005. Source identification efforts to update our GIS information have begun for this county. All available as-built construction drawings were researched and will be field verified.

An additional 77 new/unaccounted for stormwater management facilities have been identified as being constructed in the county since January 2005 bringing our current estimate of BMPs to 324. Number of major outfalls for illicit discharge screenings is 153.

Phase of GIS Updates	% Complete
Office Research	100
Field research	25
GIS Development	20

The completed updated GIS development is anticipated by July 2010.

Montgomery County - The initial inventory, database and GIS model of drainage features were completed in January 2001. Updates for the database and GIS model were completed in September 2006. The current number of post-construction stormwater BMPs identified for this county is 266. Number of major outfalls for illicit discharge screenings is 194.

Anne Arundel County - The initial inventory, database and GIS model of drainage features were completed in August 2003. Source identification efforts to update our GIS information have begun for this county. All available as-built construction drawings were researched and will be field verified.

An additional 189 stormwater management facilities have been identified as being constructed in the county since August 2003 bringing our current estimate of BMPs to 613.

Phase of GIS Updates	% Complete
Office Research	100
Field Research	18
GIS Development	18

The completed updated GIS development is anticipated by May 2010.

Prince George's County – The inventory, database and GIS model of drainage features were completed in March 2003. Source identification efforts to update our GIS information have begun for this county. All available as-built construction drawings were researched and will be field verified.

An additional 82 stormwater management facilities have been identified as being constructed in the county since March 2003 bringing our current estimate of BMPs to 263. Number of major outfalls for illicit discharge screenings is 44.

Phase of GIS Updates	% Complete
Office Research	85
Field Research	85
GIS Development	70

The completed updated GIS development is anticipated by January 2010.

Baltimore County – The inventory, database and GIS model of drainage features were completed in March 2004. Source identification efforts to update our GIS information have begun for this county. All available as-built construction drawings were researched and will be field verified.

An additional 60 stormwater management facilities have been identified as being constructed in the county since March 2004 bringing our current estimate of BMPs to 323. Number of major outfalls for illicit discharge screenings is 262.

Phase of GIS Updates	% Complete
Office Research	100
Field research	15
GIS Development	5

The completed updated GIS development is anticipated by July 2010.

BMP along MD 43 in Baltimore County

Harford County – The inventory, database and GIS model of drainage were completed in August 2005. The current number of post-construction stormwater BMPs identified for this county 110. Number of major outfalls for illicit discharge screenings is 48.

Frederick County – The inventory, database and GIS model of drainage features were completed in August 2006. The current number of post-construction stormwater BMPs identified is 62. Number of major outfalls for illicit discharge screenings is 85.

Carroll County – The GIS development for this county was completed in May 2008. The number of post-construction stormwater facilities identified is 35. The number of major outfalls for illicit discharge screening is 104.

Charles County – The GIS development for this county was completed in May 2008. The number of post-construction stormwater facilities identified is 100. The number of major outfalls for illicit discharge screening is 85.

C.1.d Submit Source Identification Data

Examples of the source identification data for Anne Arundel, Baltimore, Howard and Prince George's counties are included in Appendix A.

C.2 Submit BMP Data

Data is included on the enclosed CD for the Urban BMP database (Table B) according to Part IV and Attachment A of the permit. We have also included a copy of our entire geodatabase with complete data for all nine counties.

C.3 Create Impervious Surface Account

This condition requires that SHA provide a detailed account of impervious surfaces owned by SHA and an account of those acres of impervious surface controlled by stormwater management, broken out by SHA engineering district. This account will be used to identify potential areas for implementing restoration activities.

We have completed the impervious accounting requirement with the completion of Prince George's county this past year and a graphic of this layer is included in Appendix B. The current accounting numbers are reflected in Table 1-5.

Work Plan

The approach we have taken in meeting this requirement is detailed below:

1. Pilot Studies – Completed. See the 2006 report for more information on these studies.
2. Impervious Layer Methodology Selection – Completed. See the 2006 report for more information on the feature analyst process.
3. Impervious Accounting Protocol – Under development. See discussion below.
4. Schedule – Completed and successfully executed.
5. Implementation – Completed.
6. Annual Reporting – Information on the 2009 impervious accounting for the nine counties is included in this report.
7. Updates to the Accounting – The MDE requested annual updates to the accounting in their September 28 comments. Because our layers are produced from ortho-photography, we will update them when the statewide ortho-photography is updated. This is anticipated to take place in 2011.

Impervious Layers

Several methods exist for developing impervious surface layers ranging from manual digitizing of data from aerial photographs or contract drawings to automated remote sensing applications using satellite or aerial photography. After some study of alternatives, SHA settled on using Feature Analyst with aerial photography. Feature Analyst is a sophisticated computer application that can delineate features of interest in digital imagery. Through a learning process, Feature Analyst is programmed to recognize spectral signatures of impervious area in aerial photography.

Because these layers are generated through a process that reads ortho-photography, there are inaccuracies. But as a general quantity representing the amount SHA owns within an entire county, we feel it is a fair estimate. See Figures 1-3 and 1-4 for example display and list of data fields. Also, see Tables 1-3 and 1-4 for meta-data on the source information used including ortho-photos and right-of-way files.

Updates to the layers will be performed using the Feature Analyst process unless better methods are developed in the future. Because of the use of ortho-photography as the base data, the process to update the layers will rely on the schedules for updating the statewide ortho-photography. It is anticipated that the next updates will occur in 2011.

It should be noted that as State regulations are adhered to for all of SHA projects, SWM is addressed for all new impervious surface areas added. The SHA/MDE water quality bank facilitates overall tracking of impervious surface added through projects. It is numerically tracked, rather than based in GIS layer tracking.

As new stormwater BMPs are constructed, the layers will be updated with treatment information within the BMP drainage areas.

Figure 1-3 Example of Impervious Layer

Simple feature class

IMPERVIOUS_AREA

Geometry *Polygon*
Contains M values *No*
Contains Z values *No*

Field name	Data type	Allow nulls	Default value	Domain	Prec-ision	Scale	Length
OBJECTID	Object ID						
SHAPE	Geometry	Yes					
STUDY_PT_ID	String	No					14
SHA_OWNED	String	No		d_Boolean			50
CAPTURE_METHOD	String	Yes		d_CaptureMethod			50
SOURCE_DATE	Date	Yes			0	0	8
COMMENT	String	Yes					200
SHAPE_Length	Double	Yes			0	0	
SHAPE_Area	Double	Yes			0	0	
SOURCE_DESC	String	Yes					50
COUNTY	String	Yes					50
STATUS	String	Yes					50

Figure 1-4 Data Fields in Impervious Layer Geodatabase

Table 1-3 Meta-Data for Impervious layers

County	Ortho Capture Date	Ortho Source	Pixel Size
Anne Arundel	Spring 2005	County	6 inch
Baltimore	Spring 2005	County	1 foot
Carroll	Spring 2000	County	1 foot
Charles	Spring 2004	County	0.25 meter
Frederick	Spring 2006	County	6 inch
Harford	Spring 2004	County	1 foot
Howard	Spring 2006	County	6 inch
Montgomery	Spring 2006	County	1 foot
Prince Georges	Spring 2007	State	6 inch

Table 1-4 Right-of-Way (ROW) Layer Meta-Data

County	ROW Source	Property Data Source	Year
Anne Arundel	Vector parcel layer	County	2005
Baltimore	Vector parcel layer	County	2007
Carroll	Spring 2000	County	2007
Charles	Spring 2004	Centerline buffer /MD Property View	2002
Frederick	Vector parcel layer	County	2006
Harford	Vector parcel layer	County	2005
Howard	Vector parcel layer	County	2006
Montgomery	Vector parcel layer	County	2007
Prince Georges	Vector parcel layer	County	2008

Note: Metadata was not available to indicate the year that the ROW Source data was created. The date in the year column is assumed by the date tag of the files provided.

Impervious Accounting

The current criterion for impervious treatment is structural stormwater BMPs. Pavement being treated by grass swales or other non-structural measures is not accounted for at this time. However, as the new 2007 Stormwater Law regulations come into effect, we will begin to track and account for the environmental site design (ESD) measures that are taken to treat impervious surfaces. These can include micro-scale practices such as submerged gravel wetlands, landscape infiltration, infiltration berms, micro-bioretention, rain gardens, swales and enhanced filters as well as non-structural practices such as permeable pavement, reinforced turf, disconnection of non-rooftop runoff, sheet flow to conservation areas.

In addition to this, many segments of SHA roadways are currently treated by non-structural methods such as swales. We are beginning the process of identifying those segments and quantifying the additional impervious that can be designated as treated. While our layers will not be updated annually, our impervious accounting treatment numbers will be updated annually to reflect all of these additions to the accounting.

Some issues that this approach does not address include the following:

- Distinguish between Restoration Credit (as required in this permit) and treatment credit associated with a roadway project.
- Allow for treatment provided by others. Because SHA often enters into agreements with adjacent developers to share stormwater facilities, impervious surfaces not owned by SHA are often treated by SHA stormwater BMPs. Also, SHA impervious may drain to facilities owned by others without any agreements. For this reason, we have added two additional categories of impervious surfaces to be considered in our impervious accounting: non-SHA impervious treated by SHA and SHA impervious treated by others.

Categories of impervious treatment include:

1. SHA Impervious Not Treated,

2. SHA Impervious Treated
   a. Structural BMP Treatment
   b. Non-structural Treatment (Not shown on Figure 1-5 or Table 1-5.)

7. Non-SHA Impervious Treated by SHA BMP. (Not shown on Figure 1-5 or Table 1-5.)
   a. SHA Structural BMP Treatment
   b. SHA Non-Structural Treatment

8. SHA Impervious Treated by Others (Not shown on Figure 1-5 or Table 1-5.)
   a. Other Structural BMP Treatment
   b. Other Non-structural BMP Treatment

Table 1-5. SHA Impervious Accounting

County	Untreated SHA Impervious (AC)	Treated SHA Impervious (AC)	Total SHA Impervious in County (AC)	Percent SHA Impervious Treated
Anne Arundel	3162	633	3796	16.7%
Baltimore	3718	236	3954	6.0%
Carroll	1286	44	1330	3.3%
Charles	1364	57	1421	4.0%
Frederick	2166	187	2353	7.9%
Harford	1949	129	2078	6.2%
Howard	1982	229	2211	10.4%
Montgomery	2882	546	3428	15.9%
Prince George’s	3792	395	4187	9.4%
Totals	**22,301**	**2,456**	**24,758**	**9.9%**

Note: Numbers current to 10/2009. Treatment is by structural BMPs.

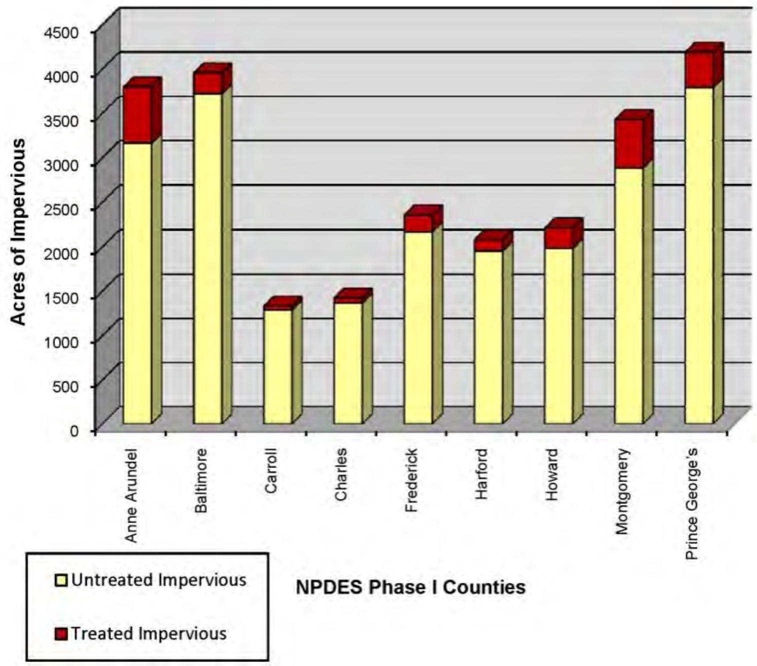


Figure 1-5 SHA-Owned Impervious Surface Treatment in 9 NPDES Counties

D Discharge Characterization

This current permit term looks at scrutinizing the available MDE dataset compiled from eleven NPDES jurisdictions and other research performed nationally to improve stormwater management programs and develop watershed restoration projects. We are continuing our efforts to understand stormwater runoff associated with highways by reviewing available literature and studies on the subject and by conducting studies to further our understanding.

Current Studies by SHA

The following studies are currently under progress by the University of Maryland, Department of Civil Engineering, and progress reports are contained in the appendices as noted:

- *Grassed Swale Pollutant Removal Efficiency Studies, Part II* – This study looks at the affect of installing check dams that are composed of native warm season grasses into the previously studied swales. Because native grasses have extensive root systems and encourage other soil processes, it was deemed useful to analyze the affects these grasses would have on our study swales and pollutant removal. The latest progress report is provided as Appendix C.

  Last year, we encountered several problems with sustaining the native grasses that make up the check dams. Because the grasses did not have adequate time for their roots to establish, we extended this study into summer 2009. Four additional storm events were monitored. The final report is anticipated for delivery in December 2009. See Figure 1-6 for a photograph of the current native grasses and Figure 1-7 for a graphic comparing rooting depths of native grasses to Kentucky Bluegrass.

Figure 1-6 Native Grass Check Dams at Study Swale

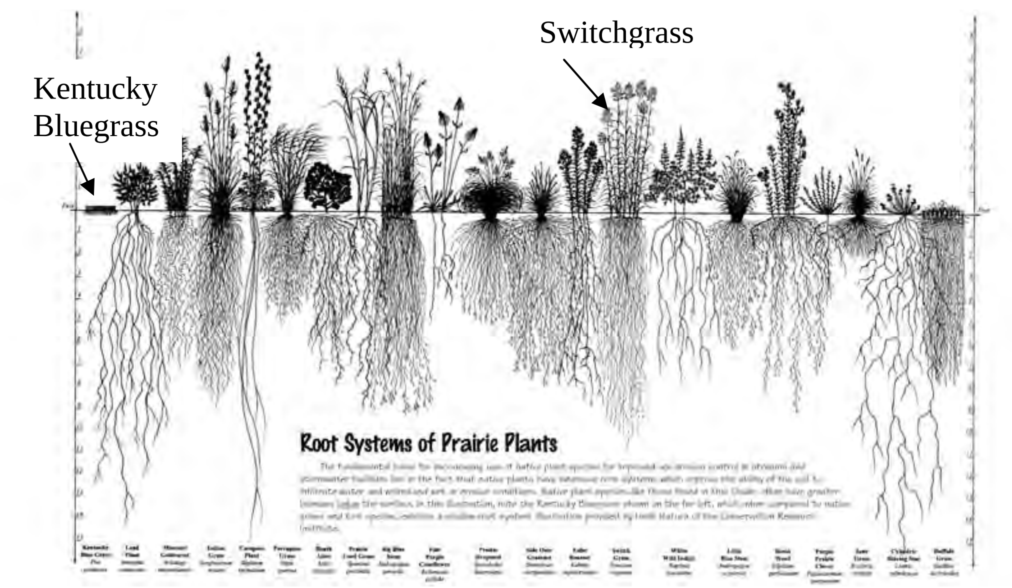


Figure 1-7 Rooting Depths of Various Native Grasses Compared to Kentucky Bluegrass

- *Develop Optimum Mix for Bioretention Soil Media* – This study was initiated in August 2008. Although new research continues to address arising challenges, bioretention is still a very immature technology and a number of problems and questions remain. One focal point of several questions concerns the media employed in the bioretention facility. The media controls many of the critical performance functions in bioretention (filtration, infiltration, adsorption, microbial substrate, vegetative support), yet we are far from having a good understanding about the critical design and operation components of the media and the resulting performance.

  Currently, no universal bioretention soil media (BSM) specification exists, even throughout the state of Maryland. SHA, Prince Georges County, Montgomery County, and the Maryland Department of the

Environment all have different requirements. Yet none of these specifications are based on direct performance information. This study seeks to develop a BSM mix that can be utilized by all jurisdictions.

Optimization of media design was investigated for pollutant capture, with a focus on the nutrients phosphorus and nitrogen. A review of current literature and critical analysis of amendment options based on treatment capacity, cost, and local availability led to the selection of aluminum water treatment residual (WTR) as an ideal BSM amendment for phosphorus capture and retention.

This, coupled with other measures such as vigorous facility vegetative cover, is hypothesized to be ideal for nutrient removal from stormwater in bioretention facilities. Sorption isotherms were first developed to determine the appropriate BSM amendment content for effective and long term phosphorus capture, found to be approximately 5% WTR by weight. Hardwood bark mulch (HBM) was investigated as an organic matter amendment and shown to potentially increase BSM P capture further. Next steps include vegetated column studies to investigate the system performance of a WTR amended bioretention facility. A copy of the progress report is included in Appendix E.

View of BMP 130348 at Outflow Point – Failed Infiltration Basin Currently Monitored

Instrumentation at Failed Infiltration Basin No. 130348

- *Wet Infiltration Basin Transitional Performance Studies* – This study was initiated in August 2008. One particular practice of interest to SHA is the infiltration basin. Over the past few decades, a multitude of infiltration basins have been constructed for stormwater management. Inspections have shown that these infiltration basins are no longer functioning as originally intended and designed and that a separate ecological function appears to have developed. These practices have gradually transformed into wetland-like practices that appear to have both water quality and hydrologic management functions. Therefore, rather than a failure, these sites should be classified as functioning, stormwater management practices and this study seeks to develop evidence to this end.

  Target pollutants to be monitored include total suspended solids (TSS), nitrate, nitrite, total Kjeldahl nitrogen (TKN), total phosphorus, copper, lead, zinc, and chloride. These pollutants are of the greatest concern in roadway runoff because their concentrations often exceed the limits set by anticipated total maximum daily loads (TMDL) requirements.

  Only one set of grab samples has been taken and analyzed so far so not conclusive discussion can be provided at this point. A copy of the progress report is included in Appendix D.

Previously Completed Studies by SHA

The following studies have been completed by SHA and were included in previous annual reports:

- *Literature Review: BMP Efficiencies for Highway and Urban Stormwater Runoff* – This literature search looked at current available resources for evaluating the effectiveness of stormwater management technologies in removing pollutants and methodologies for evaluating this effectiveness. The report included information on reporting parameters of BMPs, grass swale, bioretention, basins, vegetated buffer strips, sand filters and wetlands.
- *Low Impact Development Implementation Studies at Mt. Rainier, MD,* October 2006.
- *Grass Swale Study – Part II,* October 2006.

The following studies were completed by SHA during the previous permit term:

- *Annual Report: Pindell School Road Storm Sampling*, KCI, March 7, 2000;
- *National Highway Runoff Study: Comparison to MSHA Sampling Results*, KCI, December 2001;
- *Dulaney Valley Road I-695 Interchange Stream Monitoring at the Tributary to Hampton Branch*, KCI, Annual Reports dating 2000 to 2003.

Additional Resources

The following additional resources were listed in the 2007 report and SHA is continuing to review and digest the information contained in them in order to improve our processes and to strategically move our program forward:

<u>Highway Runoff Discharge Characterization</u>

- *The National Runoff Data and Methodology Synthesis, Publication No FHWA-EP-03-054 -055, -056, 2003*.

<u>Stormwater Best Management Practices</u>

- *Evaluation of Best Management Practices for Highway Runoff Control*, NCHRP Report 565.
- *Controlling Urban Runoff: Practical Manual for Planning and Designing Urban BMPs*, Metropolitan Washington Council of Governments, 1987.

<u>Deicing Materials</u>

- *Guidelines for Selection of Snow and Ice Control Materials to Mitigate Environmental Impacts*, NCHRP Report 577.
- *Assessing the Role of Road Salt Run-off on the Critical Ecological interactions that Regulate Carbon Processing in Small, Headwter Streams in the Chesapeake Bay Watershed*, Chris Swann, MWRRC, 2006.
- *Pollutant Mass Flushing Characterization of Highway Stormwater Runoff from an Ultra-Urban Area*, Flint and Davis, June 2007.
- *Choosing Appropriate Vegetation for Salt-Impacted Roadways*, Center for Watershed Protection Technical Note # 56.
- *Rating Deicing Agents: Road Salt Stands Firm*, Center for Watershed Protection Technical Note # 55.
- *Increased Salinization of Fresh Water in the Northeastern United States*, Kaushal, Groffman, Likens, Belt, Stack, Kelly, Band and Fisher, August 2005.

<u>Total Maximum Daily Loads</u>

- *Maryland's 2006 TMDL Implementation Guidance for Local Governments*, Maryland Department of the Environment, 2006.
- *Maryland's Chesapeake Bay Tributary Strategy Statewide Implementation Plan*, Watershed Services Center, Maryland Department of Natural Resources, August 2, 2007.

<u>Illicit Discharges</u>

- *Methods for Detection of Inappropriate Discharges to Storm Drainage Systems*, Robert Pitt, University of Alabama, November 2001.

- *Illicit Discharge, Detection and Elimination: A Guidance Manual for Program Development and Technical Assessments*, Center for Watershed Protection, October 2004.

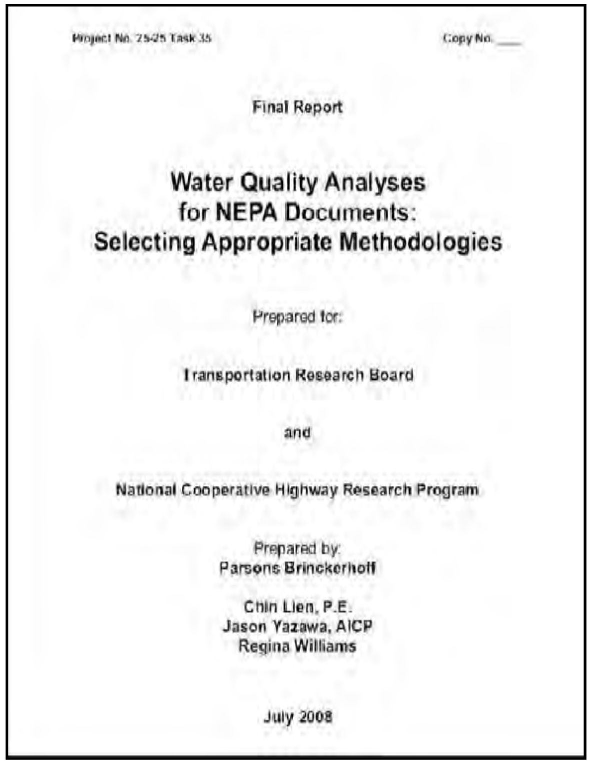
<u>Watershed-Based Strategies</u>

- *Water Quality Analyses for NEPA Documents: Selecting Appropriate Methodologies*, AASHTO & NCHRP, July 2008
- *A User's Guide to Watershed Planning in Maryland*, Center for Watershed Protection, December 2005.
- *Watershed-Based National Pollutant Discharge Elimination System (NPDES) Permitting Implementation Guidance*, Environmental Protection Agency, December 2003.

NEW! <u>Pollutant Load Reductions</u>

- Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs, Metropolitan Washington Council of Governments, July 1987.
- *Pollutant Loadings and Impacts from Highway STormwater Runoff, Volumes I-IV: Design Procedures, FHWA/RD-88-0006-9*, Driscoll & Strecker, Federal Highway Administration, 1990 (We are currently attempting to locate a copy of this document)

Using the literature and research documented above, we are pursuing further understanding of the pollutant removal capabilities of the various BMPs discussed in the *2000 Maryland Stormwater Design Manual* as well as other innovative stormwater management techniques. We are also pursuing understanding of pollutants and their transport and uptake mechanisms, watershed based emphasis to stormwater and the efforts by Maryland to achieve watershed level restoration.



Project No. 25-25 Task 35 Copy No. ___

Final Report

Water Quality Analyses
for NEPA Documents:
Selecting Appropriate Methodologies

Prepared for:

Transportation Research Board

and

National Cooperative Highway Research Program

Prepared by:
Parsons Brinckerhoff

Chin Lien, P.E.
Jason Yazawa, AICP
Regina Williams

July 2008

Study Utilized in Developing US 301 Analyses Methodologies

E Management Program

A management program is required to limit the discharge of stormwater pollutants to the maximum extent practicable. The idea is to eliminate pollutants before they enter the waterways. This program includes provisions for environmental design, erosion and sediment control, stormwater management, industrial facility maintenance, illicit connection detection and elimination, and personnel and citizen education concerning stormwater and pollutant minimization.

E.1 Environmental Design Practices

This permit condition requires that SHA take necessary steps to minimize adverse impacts to the environment through the roadway planning, design and construction process. Engaging the public in these processes is also required.

The Maryland State Highway Administration has a strong environmental commitment that will only increase as the new Stormwater Management Act of 2007 is implemented in May 2010. Through this legislation, emphasis will be placed on the use of environmental site design (ESD) techniques. We are actively working ESD measures into roadway projects in anticipation of the May 2010 implementation.

SHA also continues to adhere to processes that ensure that environmental and cultural resources are evaluated in the planning, design, construction and maintenance of our roadway network. This includes providing opportunity for public involvement and incorporating context sensitive design and solution principles. We also ensure that all environmental permitting requirements are met by providing training to our personnel (see E.6.b below) and creating and utilizing software to track permitting needs on projects as they move through the design, advertisement and construction processes.

NEPA/MEPA Process

Our National Environmental Policy Act/ Maryland Environmental Policy Act (NEPA/MEPA) design and planning process, includes environmental assessments for any project proposed within SHA right-of-way or utilizing state or federal funding. This includes projects granted Transportation Enhancement Program funds that are carried out by other jurisdictions. The environmental assessments determine the direction environmental documentation must take, whether Categorical Exclusion (CE), Finding of No Significant Impact (FONSI) or Environmental Impact Statement (EIS). Environmental assessments include landuse considerations, water use considerations, air use considerations, plants and animals, socio-economic, and other considerations.

Increasingly, SHA is evaluating stormwater needs during the NEPA process. This movement to timing stormwater concepts in planning has affected our development process in several ways. Beginning the stormwater process earlier allows us to present more realistic concepts during public meetings and allows us to more accurately assess right-of-way needs. The drawback to this approach, however, can be that assumptions made in terms of the stormwater requirements may not be the final approved requirements. This last affect can have negative impacts on our permit approval process, public expectations, right-of-way acquisitions and design schedules. SHA encourages the stormwater regulatory reviewers to participate in the planning process by attending interagency meetings, reviewing concept plans and providing valid comments and concept approvals at the planning stage in the design.

It should be noted, however, that the planning process for major projects and the project development timeline can be greater than cycles of regulatory changes for water quality. This further introduces complexity in decision making and public perception of accuracies of SHA projects and processes.

Effort is made to avoid or minimize environmental impacts. If impacts are unavoidable, however, mitigation is provided and monitored per regulatory requirements.

Environmental Research

In addition to the research studies mentioned above in Section D, Discharge Characterization, SHA has also pursued research and development studies to improve our understanding of the impacts certain BMPs have on the environment. Past studies include:

- *Thermal Impact of Underground Stormwater Management Storage Facilities on Highway Stormwater Runoff* – The goal of the study was to identify and document the thermal reduction effects on stormwater in underground storage facilities. Three sites were identified and monitoring equipment was installed at two of the sites along I-83 in Baltimore County. Instrumentation was installed to measure temperature at the inflow and outflow. The study concluded that the thermal reduction benefits of underground storage are minimal and should not be considered a significant factor in designing to reduce thermal impacts. The reasons cited include low residency time, limited thermal transfer potential, principal thermal reduction due to reduction in direct solar radiation. No further studies on underground storage and thermal reduction are planned at this time. The final report was included as Appendix F in the 2008 annual report.

- *Mosquito Surveillance/Control Program* – This three-year study conducted by Millersville University for Maryland SHA and the final report and conclusions were included in the 2006 annual report. In this study, SHA investigated the connection between West Nile Virus (WNV) transmission and stormwater management facilities. West Nile viral encephalitis is a zoonosis in which people and horses are incidentally infected by mosquitoes that feed on both bird and mammalian hosts. No further work on mosquito issues is planned at this time as we are referencing the MD Department of Agriculture site for additional information and have consulted with them for eradication efforts. The final report was included as Appendix E of the 2006 annual report.

- *Prediction of Temperature at the Outlet of Stormwater Sand Filters* **–** This study was begun in 2003 and the intent was to create a computer model of a sand filter BMP that will allow prediction of outlet temperature as a function of time. The approach is physics based, depending on energy and mass balances, and heat and mass transfer predictions. Rather than uniform flow, water tends to flow in channels or fingers through sand and other soils and this flow type is called preferential flow. This preferential flow resulted in less contact with sand particles and less transference of heat from the water to the sand. No further work on this predictive model is planned at this time. The final progress report was included as Appendix H in the 2007 report.

E.2 Erosion and Sediment Control

Requirements under this condition include:

a) *Use MDE's 1994 Standards and Specifications for Soil Erosion and Sediment Control, or any subsequent revisions, evaluate new products for erosion and sediment control, and assist MDE in developing new standards; and*

b) *Perform responsible personnel ("green card") certification classes to educate highway construction contractors regarding erosion and sediment control requirements. Program activity shall be recorded on MDE's "green card" database and submitted as required in Part IV of this permit.*

E.2.a MDE ESC Standards

During this past year, several changes to the MDE Erosion and Sediment Control (ESC) program occurred. Changes included the re-issued NPDES Construction Activity Permit and the Draft *2010 Maryland Standards and Specifications for Soil Erosion and Sediment Control*.

SHA continues to comply with Maryland State and Federal laws and regulations for erosion and sediment control (ESC) as well as MDE requirements for permitting. This includes implementing the current *1994 Standards and Specifications for Soil Erosion* for all projects. We will also be reviewing the new draft standards and specifications to offer comments and attend the public meetings. SHA has also participated in the development of the draft standards.

SHA has remained in compliance with the NPDES Construction Activity permit and has implemented changes in our construction inspection to adhere to new requirements. We continue to submit applications for coverage under this general permit for all qualifying roadway projects.

SHA ESC Quality Assurance Ratings

SHA continues to use our improved Quality Assurance rating system for ESC on all roadway projects. This effort improves field implementation of ESC measures by including an incentive payment to the contractor for excellent ESC performance or imposes liquidated damages on the contractor for poor ESC performance.

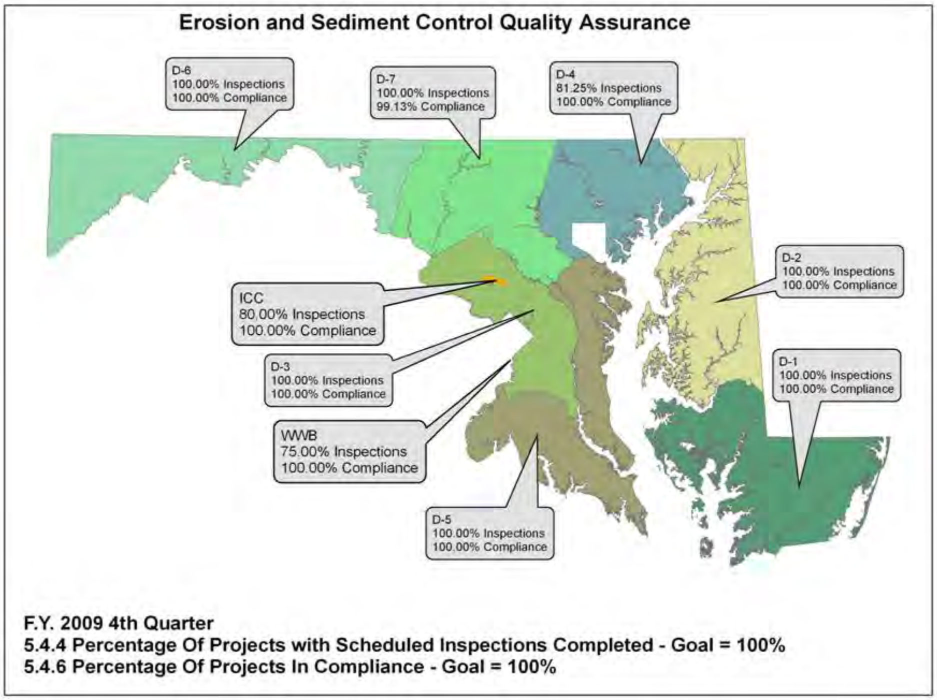


Figure 1-8 Erosion and Sediment Control Quality Assurance for FY2009, Fourth Quarter

SHA tracks QA inspections and ratings for reporting to our business plan (see Figure 1-8) and StateStat. Increased numbers of inspections and better documentation have improved the overall performance of our ESC program. It has also resulted in organizational changes within SHA. The QA inspection team is now housed under the Office of Environmental Design (OED). Incentive payments are made when the contractor receives an ESC rating score of 85 or greater. This incentive payment can be made quarterly (every 3 months) for projects that continue to receive 85 or greater ratings.

Liquidated damages are imposed on the contractor if the project receives a 'D' or 'F' rating. If two ratings of 'F' are received on a project, the ESC certification issued by SHA will be revoked from the contractor's project superintendent and the ESC manager for a period of six months and until they complete and pass the certification training. This system of rewarding good performance and penalizing poor performance is expected to greatly improve contractor responsibility for ESC practices and improve water quality associated with construction activities.

Limit of Disturbance (LOD) Stationing

Another improvement to our ESC efforts is that we are now requiring designers to provide offsets and stationing on the limit of disturbance (LOD) on ESC design plans. This will give the construction contractor information in order to accurately stake out and place the LOD in the field. Ultimately, this will provide better control of project disturbance.

Turf Acceptance Standard

In order to ensure that quality turf is established along SHA rights-of-way and thereby reduce erosion and improve slope stability, the SHA Landscape Operations Division (LOD) has developed a turf inspection and acceptance process. This process requires contractors to meet minimum turf coverage percentages in order to secure final release of the project for maintenance and final payment to the contractor

Poor Turf Establishment Increases Erosion

Quality Turf Improves Soil Retention

At the time of semi-final inspection the turf on the construction project is evaluated according to the criteria below.

- Areas flatter than 4:1 should exhibit:
  - 95% coverage of Permanent Seed Mix or *Sericea lespedeza* or Special Purpose Seed Mix; and
  - Dark green color
- Areas 4:1 and steeper (tracked with a bulldozer) should exhibit:
  - 95% coverage of vegetation with 50% coverage of Permanent Seed Mix or *Sericea lespedeza* or Special Purpose Seed Mix; and
  - Dark green color

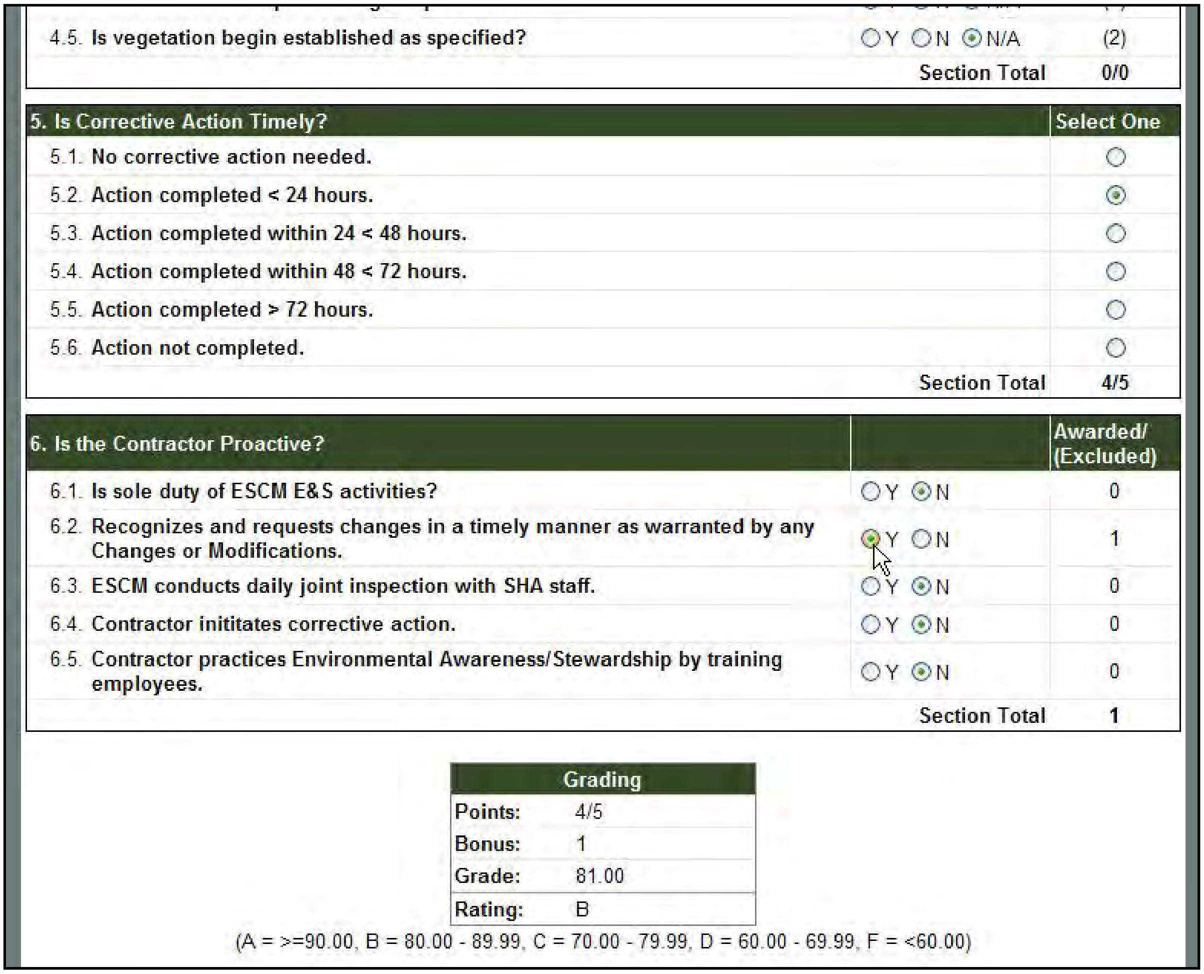
SHA ESC Field Guide

The SHA Field Guide to Erosion and Sediment Control was completed and is being distributed to construction engineers, certified ESC managers and inspectors, and ESC designers. This field guide provides essential information in a format that is easy to access and carry.

New! ESC Quality Assurance (QA) Toolkit

This is a web-based tool that allows SHA ESC compliance field inspectors to capture inspection data directly to the database electronically for use by the HHD and OED for tracking. Prior to the development of this tool, inspections were recorded on paper forms and transferred to a database by a third party. This previous method allowed for inefficiencies and error in report tracking.

With the QA Toolkit, ESC compliance inspectors use wireless 'tough book' laptops and input inspection data directly into the database over the worldwide web. This allows SHA to house a centralized database that is accessible to many personnel including inspectors, independent environmental construction monitors, SHA senior management and environmental programs personnel. The dataset that is captured in the field can also include project details such as plan sheets and permit records. The initiative of the ESC QA Toolkit was recognized at the SHA Performance Excellence conference in 2008.



4.5. Is vegetation begin established as specified?	○Y ○N ⦿N/A	(2)
	Section Total	0/0

5. Is Corrective Action Timely?	Select One
5.1. No corrective action needed.	○
5.2. Action completed < 24 hours.	⦿
5.3. Action completed within 24 < 48 hours.	○
5.4. Action completed within 48 < 72 hours.	○
5.5. Action completed > 72 hours.	○
5.6. Action not completed.	○
Section Total	4/5

6. Is the Contractor Proactive?		Awarded/ (Excluded)
6.1. Is sole duty of ESCM E&S activities?	○Y ⦿N	0
6.2. Recognizes and requests changes in a timely manner as warranted by any Changes or Modifications.	⦿Y ○N	1
6.3. ESCM conducts daily joint inspection with SHA staff.	○Y ⦿N	0
6.4. Contractor inititates corrective action.	○Y ⦿N	0
6.5. Contractor practices Environmental Awareness/Stewardship by training employees.	○Y ⦿N	0
	Section Total	1

Grading	
Points:	4/5
Bonus:	1
Grade:	81.00
Rating:	B

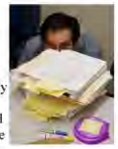
(A = >=90.00, B = 80.00 - 89.99, C = 70.00 - 79.99, D = 60.00 - 69.99, F = <60.00)

Figure 1-9 Screen Shot of ESC QA Toolkit

QA Toolkit

Process Improvements for the ESC QA Ratings Program

Old Paper Intensive Process



- Construction inspector completes a paper QA Ratings form in the field for construction sites assigned;
- A collection of QA Ratings forms is sent via inter-office mail on a monthly or quarterly basis, depending on the construction inspector's schedule and availability of data entry person at the design office;
- Data from QA Ratings forms is reviewed by data entry person at the design office and illegible information verified with the construction inspector via phone or email;
- Verified data from QA Ratings forms is entered manually, a form at a time, into a reporting database;
- Reports are run as needed from this data and provided to management for decision making and program compliance reporting purposes.

New Web-Enabled Collaborative Process

The new Web-enabled process reduces the time it takes for inspection data to flow from construction quality control inspector, who collects data in the field, to the design office that needs to receive and process the data for decision making and reporting. A secondary benefit of the new process is the elimination of transcription errors that occur when data from paper forms is reentered into a database system.

- Construction inspector uses an air-card equipped rugged tablet computer to complete QA Ratings forms online into the QA Toolkit application while in the field for construction sites assigned;
- Because QA Ratings forms are completed online, they are available to all users the moment they are entered and saved by the construction inspector, thus eliminating compilation and transmission time and also eliminating manual data input effort at the office and associated transcription errors;
- Reports are run as needed from the live data and accessible by management in real-time for decision making and program compliance reporting purposes.

Why the Team Decided to Improve the Process?

- QA Ratings forms differed from project to project making it difficult for construction inspector to track which of the several forms to use for the project, whereas a system like QA Toolkit would present the proper form for the project selected for data input by the construction inspector;
- The time lag between when inspection data was collected by construction inspectors and when it was available in the QA Ratings reporting database was several weeks, if not months, whereas a system like QA Toolkit would make it available in real-time from field to the office;
- Illegible notes on the paper form could delay data entry into the reporting database, whereas a system like QA Toolkit simplified data input through availability of standardized drop-down lists and choices on screen;

Key Drivers for Process Improvement

- **Business Plan Goal for process improvement and efficiency**
- **Centralized data repository to support the StateStat reporting initiative underway**
- **Environmental compliance and commitment**

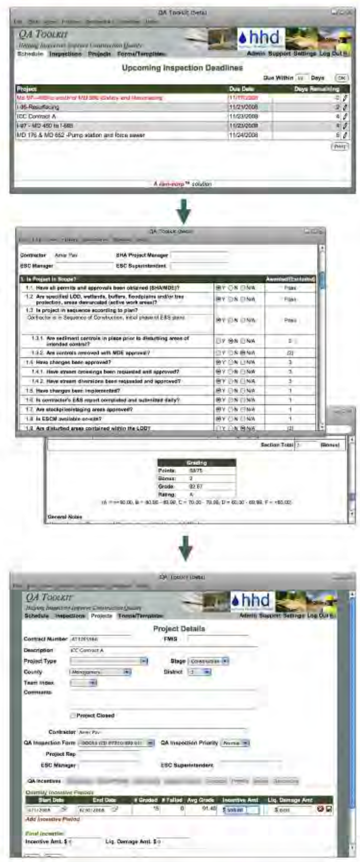
- Existence of a centralized permission-controlled role-based repository of QA Ratings data would allow SHA to make it available to environmental permitting agencies, to contractors, and to other systems such as StateStat.

Steps Taken by Team to Achieve Goal

- Setup development team with representation from across office boundaries;
- Created specification document and Project Management Plan for the development of the proposed system;
- Obtained concurrence and approval from stakeholders on the specifications, schedule, budget, and plan;
- Developed Web-based QA Toolkit application;
- Procured air-card equipped tablet computers for use by construction inspectors;
- Imported legacy data from the obsolete QA Ratings reporting database;
- Provided training to construction inspectors and conducted a pilot of the system;
- Collecting ongoing feedback and making tweaks to the system as necessary.

How the Team Gathered and Analyzed Data

- Conducted "needs discovery" meetings;
- Developed use-case diagrams;
- Created interface storyboards;
- Wrote a formal project specification document;
- Reviewed existing paper inspection forms;
- Confirmed application workflow with all team members.



Partnering Across Office Boundaries

- **Highway Hydraulics Division (Office of Highway Development)**
- **Construction Inspection Division (Office of Construction)**
- **Environmental Programs Division (Office of Environmental Design)**
- **Design Technical Services Division (Office of Highway Development)**
- **Other Stakeholders (Environmental Regulatory Agencies; Contractors)**

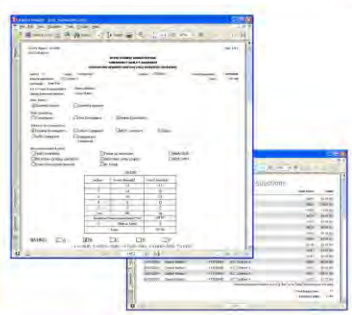


Figure 1-10 Information Board on ESC QA Toolkit

E.2.b Responsible Personnel Certification Classes (Green Card Training)

SHA continued to sponsor and perform training for ESC Responsible Personnel Certification Classes over the past year. This training is conducted by SHA for SHA personnel, consultants and contractors.

A copy of the database of trained personnel (MDE Table H, Responsible Personnel Certification Information) is included on the CD included as an attachment to this report.

SHA Basic Erosion and Sediment Control Training (BEST)

In addition to Green Card Training classes, SHA developed and implemented its own ESC Certification Program at two levels. Level I is known as BEST (Basic Erosion and Sediment Control Training). This day and a half training is aimed at contractors and field personnel and focuses on in-depth discussions of ESC design, construction and permitting requirements. This is also a prerequisite for Level II training.

The Level II training is intended for ESC design professionals. The Level II training began in June 2007.

Table 1-6 ESC Training Held by SHA (10/2008 to 9/2009)

Type of Training	No. of Participants
Responsible Personnel (Green Card)	964
BEST Level I (Yellow Card)	497
BEST Level II (Designer's Training)	19

E.3 Stormwater Management

The continuance of an effective stormwater management program is emphasis of this permit condition. Requirements under this condition include:

a) *Implement the stormwater management design principles, methods, and practices found in the 2000 Maryland Stormwater Design Manual and COMAR;*

b) *Implement a BMP inspection and maintenance program to inspect all stormwater management facilities at least once every three years and perform all routine maintenance (e.g., mowing, trash removal, tarring risers, etc.) within one year of the inspection; and*

c) *Document BMPs in need of significant maintenance work and prioritize these facilities for repair. The SHA shall provide in its annual reports detailed schedules for performing all significant BMP repair work.*

E.3.a Implement SWM Design Manual and Regulations

SHA continues to comply with Maryland State and Federal laws and regulations for stormwater management (SWM) as well as MDE requirements for permitting. We also continue to implement the practices found in the *2000 Maryland Stormwater Design Manual* and *Maryland Stormwater Management Guidelines for State and Federal Projects, July 2001* for all projects. Permitting needs are tracked for projects statewide through our Permit Tracker software tool.

We have also implemented ESD design on several projects that are currently under design. This is the revised Chapter 5 of the *2000 Maryland Stormwater Design Manual*. We await issuance of the revised State and Federal Guidelines.

E.3.b Implement BMP Inspection & Maintenance Program

Our continuing Stormwater Facility Program (managed by Ms. Dana Havlik) inspects, evaluates, maintains, remediates and enhances SHA BMP assets to maintain and improve water quality and protect sensitive water resources. Inspections are conducted every three years as part of the NPDES source identification and update effort (see Section C, above). Maintenance and remediation efforts are accomplished after the inspection data has been evaluated and ranked according to SHA rating criteria.

Details of the Stormwater Facility Program are included as Part 3 of this document. Discussion of inspection results and maintenance, remediation, retrofit and enhancement efforts undertaken over the past year is included in that section.

As-Built Certification Process

SHA continues with our SWM facility as-built certification process. This process requires the design engineer to coordinate with MDE on the completion of as-built checklists and tabulations. The contractor is then required to inspect and certify the facility construction according to the approved design plans. Additional requirements are imposed upon the contractor by SHA that go above and beyond the certification required by MDE. This includes certification of facility plantings and permanent turf establishment. SHA has made the delivery of this certification a separate pay item. A copy of the revised As-Built Certification special provision was included the 2006 annual report.

Copies of the final approved as-built certifications are retained by SHA and integrated into the storm drain and BMP GIS/database. This information is then used as source identification updates are planned and assigned.

We are finding that compliance by the contractors is not consistent, and we are re-evaluating our process to determine a more effective means to achieve 100% compliance with this requirement.

E.3.c Document Significant BMP Maintenance

See Part 3 for SWM Facility Program updates on major maintenance, remediation and retrofits.

E.4 Highway Maintenance

Requirements under this condition include:

a) *Clean inlets and sweep streets;*
b) *Reduce the use of pesticides, herbicides, and fertilizers through the use of integrated pest management (IPM);*
c) *Manage winter weather deicing operations trough continual improvement of materials and effective decision making;*
d) *Ensure that all SHA facilities identified by the Clean Water Act (CWA) as being industrial activities have NPDES industrial general permit coverage; and*
e) *Develop a "Statewide Shop Improvement Plan" for SHA vehicle maintenance facilities to address pollution prevention and treatment requirements.*

E.4.a Inlet Cleaning and Street Sweeping

Mechanical sweeping of the roadway is essential in the collection and disposal of loose material, debris and litter into approved landfills. This material, such as dirt and sand, collects along curbs and gutters, bridge parapets/curbs, inlets and outlet pipes. Sweeping prevents buildup along sections of roadway and allows for the free flow of water from the highway, to enter into the highway drainage system.

The SHA desired maintenance condition is 95% of the traveled roadway is clear of loose material or debris. In addition, 95% of the closed sections (curb and gutter) have less than 1 inch depth of loose material or debris, or excessive vegetation that can capture debris, in the curb and gutter.

In addition to street sweeping, SHA owns and operates four vacuum pump trucks that routinely clean storm drain inlets along roadways. Sediment and trash make up the majority of the material that is removed. The vacuum trucks operate in central Maryland, spanning the following Counties: Anne Arundel, Baltimore, Calvert, Carroll, Charles, Frederick, Harford, Howard, Montgomery, Prince George's and St. Mary's. This practice ensures safer roadways through ensuring proper drainage and improves water quality in Maryland's streams.

In the next year, SHA Highway Hydraulics Division will be working with the SHA Office of Maintenance to document current routes, to extend these activities to watershed-based, priority roadways and to characterize and quantify material and debris removed as a result of these activities.

Vacuum Pump Truck

E.4.b Reduction of Pesticides, Herbicides and Fertilizers

SHA has standards for maintaining the highway system. One of these standards is the *SHA Integrated Vegetation Management Manual for Maryland Highways, October 2003* (IVMM). This manual incorporates the major activities involved in the management of roadside vegetation including application of herbicides, mowing and the management of woody vegetation. In order to maximize the efficiency of funds and to protect the roadside environment, an integration of these activities is employed.

Herbicide Application

Herbicides are selected based upon their safety to the environment and personnel, as well as for economical performance. In order to ensure that herbicides are applied safely to roadside target species, herbicide supervisory and application personnel are thoroughly trained, registered and/or certified by at least one of the following:

- University of Maryland
- Maryland Department of Agriculture
- SHA.

Herbicide application equipment is routinely inspected and calibrated to ensure that applications are accurately applied in accordance to the IVMM, Maryland State law and the herbicide label.

Nutrient Management Plans

The need for Nutrient Management Plans (NMP) is determined by SHA for all roadway projects according to State law (COMAR 15.20.04-08 – Nutrient Management Regulations). NMPs are developed by the Landscape Operations Division (LOD), Technical Resources Team (TRT) and the need for a NMP is at the discretion of the TRT.

The application of fertilizer is performed based upon soil sampling and testing for major plant nutrients such as phosphorus and potash. Once these plant nutrient levels are determined, a NMP is developed for both construction and maintenance. Certain major fertilizer nutrients are reduced due to adequate soil levels.

Mowing Reduction/Native Meadows

A major initiative at the SHA is to reduce the extent of mowed areas within our right-of-way. Along with this initiative, several pilot projects have been completed to install and maintain native meadow areas. Ultimately this practice will further reduce the need for fertilizer and herbicide application.

E.4.c Winter Deicing Operations

SHA continues to test and evaluate new winter materials, equipment and strategies in an on-going effort to improve the level of service provided to motorists during winter storms while at the same time minimizing the impact of its operations on the environment.

One method employed to decrease the overall application of deicing materials is to increase application of deicing materials prior to and in the early stages of a winter storm (anti-icing). This prevents snow and ice from bonding to the surface of roads and bridges and ultimately leads to lower material usage at the conclusion of storm events, thus lessening the overall usage of deicers. In addition, SHA has expanded its ‘sensible salting’ training of State and hired equipment operators in an on-going effort to decrease the use of deicing materials without jeopardizing the safety and mobility of motorists during and after winter storms. Table 1-7 lists materials used by SHA in winter deicing operations.

Table 1-7 Winter Materials used by SHA

Material	Characteristics
Sodium Chloride (Rock and Solar Salt)	The principle winter material used by SHA. Effective down to 20° F and is relatively inexpensive.
Abrasives	These include sand and crushed stone and are used to increase traction for motorists during storms. Abrasives have no snow melting capability.
Calcium Chloride	A solid (flake) winter material used during extremely cold winter storms. SHA uses limited amounts of calcium chloride.
Salt Brine	Liquid sodium chloride or liquefied salt is a solution that can be used as an anti-icer on highways prior to the onset of storms, or as a deicer on highways during a storm. Used extensively by SHA. Freeze point of -6° F.
Magnesium Chloride (Mag)	A liquid winter material used by SHA for deicing operations in its northern and western counties. It has a freeze point of 26 degrees and has proven cost effective in colder regions.
Caliber M-100	A magnesium chloride-based deicer with an agricultural additive. Its very low freeze point makes it ideal for use in Garrett County.
Potassium Acetate	A costly, environmentally friendly, liquid material used at SHA's two automated bridge anti-icing system sites in Allegany County.

Understanding Impacts of Deicing Chemicals

We are also pursuing research to understand the impact deicing chemicals have on surrounding ecosystems and organisms. See Section D, Discharge Characterization, for a list of resources we are studying.

E.4.d NPDES Industrial Permit Coverage

As discussed in the previous Annual Report, SHA developed and implemented a Compliance Focused Environmental Management System (CFEMS) to ensure multi-media compliance at all maintenance facilities statewide. The CFEMS covers procedures for management of environmental compliance issues, including those related to Industrial NPDES at maintenance facilities, such as spill response, material storage and vehicle washing. It includes the implementation of Standard Operating Procedures (SOPs), routine compliance inspections and environmental training covering a variety of media areas including stormwater management and spill prevention and response.

The CFEMS is being implemented in a phased approach. As stated in previous Annual Reports, Phase I environmental assessments at the SHA primary maintenance facilities were completed in the spring of 2007. Phase II compliance assessments, covering 65 satellite and salt storage facilities, were completed in the summer of 2009. As shown in Table 1-8 below, certain Phase II facilities are currently covered under the General Discharge Permit (02-SW). The permit status of these and other Phase II facilities will be revaluated based on the recent compliance assessments. SHA is currently compiling the results of the Phase II assessments and will ensure all stormwater requirements are met, i.e. permit coverage and Stormwater Pollution Prevention Plan (SWPPP) development. The SHA Environmental Compliance Division (ECD) will also begin routine inspections at Phase II facilities through its District Environmental Coordinators (DEC) to ensure stormwater pollution prevention BMPs are implemented. The DECs are responsible for ensuring compliance with applicable permits, plans and regulations at facilities in their region.

Subsequent phases will expand the CFEMS to other SHA facilities and operations. These facilities will be assessed for stormwater permitting needs at this time. The SHA ECD also continues to encourage maintenance facilities to present funding requests for stormwater related improvements such as erosion stabilization, material storage improvements, and spill prevention / containment devices.

E.4.e Statewide Shop Improvement Plans

As described above, SHA continues to maintain an effective Industrial Stormwater NPDES Program through ECD to ensure pollution prevention and permit requirements are being met at SHA maintenance facilities. Beginning in 2008 and continuing through 2009 SHA performed detailed site assessments at primary maintenance facilities to gather information used to update the 2005 SWPPPs and Spill Prevention, Control, and Countermeasure Plans (SPCCP). SHA recently completed final versions of SPCCPs for 27 of the primary maintenance facilities and SWPPPs for all 29 primary maintenance facilities.

Throughout 2009, SHA has continued to address potential stormwater pollution issues by implementing Best Management Practices (BMPs) and designing / constructing capital improvements. BMPs were identified during pollution prevention plan updates and routine inspections for Phase I facilities (primary maintenance shops) and initial assessments of Phase II facilities (satellite and salt storage facilities). The status of BMP implementation for maintenance facilities is tracked by each District Environmental Coordinator during routine inspections. Potential capital improvements are prioritized based on risk to human health and the environment and funding availability. The following list details the major pollution prevention efforts and maintenance facility improvements since the last annual report.

Completed Projects:

- Vehicle wash bay treatment system upgrade completed for Leonardtown maintenance facility
- Finalized SPCCPs at 27 primary maintenance facilities
- Finalized SWPPPs at all 29 primary maintenance facilities
- Sewer connection construction completion for Hanover Complex vehicle maintenance and wash bays
- Material storage structures completed at multiple facilities statewide
- Initial assessments of satellite and salt storage facilities (Phase II) completed
- Double-walled ASTs installed at several maintenance shops per SPCC requirements
- Wetland / waterway delineations completed at primary maintenance facilities
- Initial round of multimedia compliance training completed using District Environmental Coordinators (DECs)

Ongoing Projects:

- Statewide oil-water separator maintenance program
- Statewide discharge sampling and reporting program for facilities with Individual Discharge Permits
- Routine compliance inspections at all Phase I facilities (primary maintenance) and Phase II facilities (satellite and salt storage)

Initiated Projects:

- Battery Storage / Spill Kit procurement for satellite and salt storage (Phase II) facilities
- Multimedia computer-based training initiated Statewide
- Grit Chamber assessment and upgrade design at Prince Frederick and Marlboro maintenance facilities

Spill Pallets Used at SHA Maintenance Shops

Table 1-8 Industrial NPDES Permit Status

District	Maintenance Facility	Permit Type
1	Berlin[1]	General
	Cambridge	General
	Princess Anne	General
	Salisbury	General
	Snow Hill	General
2	Centreville	Individual – SW
	Chestertown	General
	Denton	General
	Easton	General
	Elkton	General
	Millington[1]	General
3	Fairland	General
	Gaithersburg	General
	Kensington[1]	General
	Laurel	General
	Marlboro	General
	Metro/Landover[1]	General
4	Churchville	Individual – SW
	Golden Ring	General
	Hereford	Individual – SW[2]
	Owings Mills	General
5	Annapolis	General
	Glen Burnie	General
	La Plata	General
	Leonardtown	Individual – SW[2]
	Prince Frederick	General
6	Frostburg[1]	General
	Hagerstown	General
	Hancock	General
	Keyser's Ridge	Individual – GW
	Laval	General
	Oakland	General
7	Dayton	Individual – SW[2]
	Frederick	General
	Thurmont[1]	General
	Westminster	General
Offices / Other Facilities	Brooklandville Complex[3]	General
	Hanover Complex	General

Note: SW = Surface Water, GW = Groundwater

[1] Phase II Facility (Satellite / Salt Storage Facility)

[2] Currently collecting all wastewater for pump and treat in a storage tank - therefore generating no discharge

[3] Property in flux - no longer used by SHA

Table 1-9 shows the SHA capital expenditures towards industrial pollution prevention BMPs from the current and past four fiscal years. Projected expenditure for 2010 are also included.

Table 1-9 Capital Expenditures for Pollution Prevention BMPs

Fiscal Year	Expenditure
2005	$ 613,210 - actual
2006	$ 592,873 - actual
2007	$ 450,608 - actual
2008	$ 590,704 - actual
2009	$ 478,889 – actual
2010	$500,000 – anticipated

E.5 Illicit Discharge Detection and Elimination

Requirements under this condition include:

a) *Conduct visual inspections of stormwater outfalls as part of its source identification and BMP inspection protocols*

b) *Document each outfall's structural, environmental and functional attributes;*

c) *Investigate outfalls suspected of having illicit connections by using storm drain maps, chemical screening, dye testing, and other viable means;*

d) *Use appropriate enforcement procedures for eliminating illicit connections or refer violators to MDE for enforcement and permitting.*

e) *Coordinate with surrounding jurisdictions when illicit connections originate from beyond SHA's rights-of-way; and*

f) *Annually report illicit discharge detection and elimination activities as specified in Part IV of this permit. Annual reports shall include any requests and accompanying justifications for proposed modifications to the detection and elimination program.*

E.5.a Visual Inspections of Outfalls

The Storm Drain and Outfall Inspection and Remediation Program (SOIRP) is headed by Mr. Brandon Scott. This program focuses on the physical conditions and structural functionality of SHA's drainage systems, primarily culvert outfall conditions. Inspections for the SOIRP program will result in developing strategies for maintaining, repairing or otherwise remediating storm drain and outfall stabilization problems. The resulting remediation actions can be constructed through our open-end construction contracts, transportation enhancement fund projects or advertised projects. Projects have been developed to address stabilization issues in Harford and Baltimore Counties.

E.5.b Document each Outfall's Attributes

SOIRP outfall inspections are currently being conducted on the outfalls in Prince George's and Anne Arundel Counties. Because these county updates are not completed, the ratings are not presented here. Although GIS updates have also been initiated in Baltimore and Howard counties, due to budget cutbacks, the outfall inspections were eliminated from the update tasks for these two counties.

Inspections using the SHA SOIRP Program outfall inspection protocol were previously conducted on seven counties: Montgomery, Baltimore, Carroll, Charles, Frederick, Harford and Howard. Based on the needs determined from the inspections, SHA is currently in the design phase for Baltimore and Harford County sites. Information on the Baltimore and Harford county outfall remediation projects was included in the 2008 annual report. The Baltimore County outfall sites were split into two phases and the first phase, consisting of 10 outfalls, has completed construction. The second phase of Baltimore sites and all of the Harford sites are on hold due to funding cut backs. Other sources of grant funding may be pursued if appropriate.

E.5.c Illicit Connection Investigations

Currently, illicit discharge screenings are being conducted in Baltimore, Anne Arundel, Howard and Prince George's counties. As illicit discharges are found we currently are sending the report to the local NPDES coordinator for elimination. One report has been sent to Steve Stewart at Baltimore County so far for this year.

Illicit Discharge with Presence of Detergents and Ammonia discovered in Baltimore County

E.5.d Use Appropriate Enforcement Procedures

We find that our screening process is proving to be a success in identifying, tracking and documenting illicit discharges (ID). However our current elimination process is not proving to be effective. Because the State highway Administration is a land development agency rather than a governing body such as a county or municipality; we cannot enact and enforce legislation. We can encourage the State's attorney's office on our behalf, but the ultimate authority to enact and enforce legislation concerning illicit discharges lies with the local governing bodies such as counties or municipalities.

We can restrict activities within our right-of-way by removing or blocking connections but cannot enter adjacent property and enforce elimination of the discharge. Because SHA does not have authority through ordinances to issue and enforce fines for illicit discharges, we have been relying upon the jurisdiction within which our roadway facility and the illicit discharge in question are discovered.

SHA has been notifying the NPDES coordinator or their IDDE designated contact at the counties or jurisdictions in which the discharges are discovered. Elimination follow-up with this method has not been consistently reliable and SHA has determined to put in place a series of escalating steps in order to follow up on eliminating illicit discharges in a systematic manner.

Implementation of ID Elimination Process

Steps to implement the illicit discharge elimination process include the following:

1. Develop Process for Eliminating ID – Completed, see Appendix F.
2. Develop Database – Our current geodatabase tracks most of the infomormation for Table G from Attachment A of the permit. We will develop an associated database table with automatic ID numbering scheme that will assign a number to all illicit discharges found on SHA right-of-way or connecting to SHA storm drain systems. This database will track dates of initial discovery/investigation of discharges, type of discharge, location, and progress in pursuing elimination of the discharge.
3. Develop Property Owner Notification Letter – Completed, see Appendix F.
4. Update Chapter 5 – The Illicit Discharge Detection and Elimination chapter of the SHA NPDES Standard Procedures will be updated to include revised illicit discharge elimination process.

The new elimination process will be implemented November 2009. We will begin by following up with all the local jurisdictions that have received illicit discharge reports in the past and follow up with elimination of those that still exist.

E.5.f Annual Report Illicit Discharge Detection and Elimination Activities

A summary of illicit discharge detection and elimination activities for this permit term is provided in Table 1-10. The MDE database Table G for Illicit Discharge Detection and Elimination is included on the attached CD.

Table 1-10 below details the past and current illicit connections to SHA storm drain systems that have been discovered through our field inspection and screening process and the jurisdiction and date the reports were delivered for elimination enforcement.

Table 1-10 Illicit Discharge Screenings to Date

County	Outfalls Screened	Outfalls w/ Flow Observed	Illicit Discharge Reports	Delivered to Jurisdiction	Date Delivered
Frederick	46	46	16	County NPDES Coordinator	9/11/2007
Harford	53	16	1	No Records	
Howard	209	172	2	County NPDES Coordinator	01/10/2008
Montgomery	217	26	3	County NPDES Coordinator	01/10/2008
Charles	85	27	0		
Carroll	104	84	7	County NPDES Coordinator	8/14/2008
Anne Arundel[1]	101	10	0		
Prince George's[1]	163	22	0		
Baltimore[1]	77	16	1	County NPDES Coordinator	10/09/2009
Howard[1]	9	3	0		
Totals	**1059**	**422**	**30**		

Notes: 1. GIS development is currently under way but not completed.

MARYLAND ATTORNEY GENERAL
Douglas F. Gansler

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For Immediate Release
October 10, 2006

Media Contact:
Kevin Enright 410-576-6357

ROCKVILLE CAR WASH CONVICTED OF WATER POLLUTION

Maryland Attorney General J. Joseph Curran announced today that M.J.L. Corp. trading as Touch*Less II Car Wash, located at 16185 Shady Grove Road in Rockville Maryland was convicted of water pollution and ordered to pay a $5000 fine. Company President and owner Samuel Pellerito admitted that the car wash discharged its waste water into the storm drain inlet near the intersection of Shady Grove Road and MD Rt. 355 on November 10, 2005. State Highway Administration engineers investigating why the storm water management pond alongside MD Rt. 355 near Shady Grove Road contained green colored water discovered that the soapy water originated from the car wash. They traced the discharge up stream through the manholes in the storm sewer until they arrived at the car wash. At that point they took photographs of the discharge coming from a fenced in dumpster area which contained a storm drain inlet.

Montgomery County District Court Judge Stephen P. Johnson imposed a $10,000 fine on the company, suspended $5,000 and placed the car wash on one year's unsupervised probation. The judge also ordered that the line leading from the car wash to the storm drain inlet be permanently filled in and disabled.

According to the statement of facts, the discharge came from a line connected to the car wash's waste-water collection system. Although that line was supposed to have been capped and sealed in 2001, state and county inspectors discovered that the cap could be removed thus restoring the line to service. The case was investigated by the Environmental Crimes Unit of the Office of the Attorney General with assistance from the Maryland State Police, the State Highway Administration, the Maryland Department of the Environment and the Montgomery County Division of Environmental Policy and Compliance.

Attorney General of Maryland 1 (888) 743-0023 toll-free / TDD: (410) 576-6372
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SHA Worked with Environmental Crimes Unit (ECU) to Eliminate Discharge from Car Wash

E.6 Environmental Stewardship

Requirements under this condition include:

a) *Environmental Stewardship by Motorists*
   i. *Provide stream, river, lake, and estuary name signs and environmental stewardship messages where appropriate and safe,*
   ii. *Create opportunities for volunteer roadside litter control and native tree plantings; and*
   iii. *Promote combined vehicle trips, ozone alerts, fueling after dark, mass transit and other pollution reduction actions for motorist participation.*

b) *Environmental Stewardship by Employees*
   i. *Provide classes regarding stormwater management and erosion and sediment control;*
   ii. *Participate in field trips that demonstrate links between highway runoff and stream, river, and Chesapeake Bay health;*
   iii. *Provide an environmental awareness training module for all areas of SHA;*
   iv. *Provide pollution prevention training for vehicle maintenance shop personnel;*
   v. *Ensure IPM instruction and certification by the Maryland Department of Agriculture for personnel responsible for roadside vegetation maintenance; and*

vi. Promote pollution prevention by SHA employees by encouraging combined vehicle trips, carpooling, mass transit, and compressed work weeks.

E.6.a Environmental Stewardship by Motorists

SHA continues many initiatives that encourage or target public involvement and participation in water quality programs. These initiatives cover the areas of litter control, watershed partnerships, community planting efforts and public education.

SHA public involvement and participation initiatives for the past year include:

- **Annual Earth Day Celebration** – The SHA Earth Day Team sponsored the Seventh Annual Earth Day Celebration on Tuesday, April 21, 2009 at the SHA headquarters complex. The SHA NPDES program exhibited in this year's event. The program participated with an educational exhibit and manning the booth to answer questions.

  This annual event is organized by the SHA Office of Environmental Design and many volunteers from several offices at SHA Headquarters. This team brings together a diverse group of exhibitors highlighting our resources and how to best manage their use and preservation. Approximately 350 to 400 SHA employees or visitors attended the event. Additionally, 25 grade school students and 20 high school students attended.

  This year's Patuxent Clean Up was held April 4th at a tributary to the Little Patuxent in Columbia, MD near MD 175. Twenty-four volunteers participated in collecting refuse at three locations. SHA and Howard County Recreation & Parks both provided dump trucks to collect refuse that included 10 shopping carts, a car fender, a typewriter, a printer, a large wooden drawer, several feet of wooden fencing, several bicycles (some in pretty good shape) large truck tires, bicycle tires, construction materials and about 500 lbs of bagged trash. Volunteers included employees of several transportation agencies and MDOT headquarters.

Exhibitors at this year's Earth Day event included:

- BGE Right Tree, Right Place
- Baltimore City Parks and People Org.
- SHA Adopt-a-Highway Program
- Dept. of Natural Resources Maryland Biological Stream Survey
- SHA OHD Highway Hydraulics (NPDES Program)
- SHA - District 7 Deer Compost
- Chesapeake Bay Trust
- MD DNR Invasive Species
- MATTS (Mid-Atlantic Turtle and Tortoise Society)
- MDA Soil Conservation
- National Aquarium in Baltimore
- Maryland Zoo in Baltimore Scales and Bones
- Project Planning
- Chesapeake Native Nurseries
- Baltimore City DNR Reservoir Office
- Herring Run Association
- Chesapeake Bay Foundation
- Master Gardners Program (MDCE)
- DNR MBSS
- SHA OPPE Soundwalls Noise
- SHA Scenic Byways Program
- Jug Bay Wildlife Sanctuary
- MD DNR Tree-mendous Maryland Program
- Baltimore City Recreation and Parks
- SHA – LAD Landscape Design
- SHA - Plats & Surveys Sustainable Living
- Citizens for a Greener Mount Airy
- National Aquarium in Baltimore - Education Outreach
- SHA Recycles Campaign
- SHA Advanced Leadership Program (ALP) Class of 2009
- DNR Sustainability
- National Aquarium in Baltimore - Community Outreach

Photos from Annual Earth Day Celebration held April 19, 2009

Table 1-11 Adopt-a-Highway Program

County	Groups Picking Up at Least 1 Time	No. Bags	Miles Adopted
Anne Arundel	16	232	17
Baltimore	104	828	118
Carroll	42	557	40
Charles	16	342	17
Frederick	18	118	21
Harford	21	225	18
Howard	18	221	18
Montgomery	9	135	8
Prince George's	4	18	4
Totals	248	2676	265

Data extracted from the Adopt-A-Highway database for the period 10/1/08 to 9/30/09

- **Adopt-a-Highway Program –** This program encourages volunteer groups (family, business, school or civic organizations) to pick up litter along 1-3 mile stretches of non-interstate roadways four times a year for a two year period as a community service. Table 1-11 lists groups and numbers of bags collected during the reporting period.

Table 1-12 Sponsor-a-Highway Programs

County	Available Miles	Miles Sponsored
Anne Arundel	74.95	49.96
Baltimore	75.71	49.41
Carroll	0	0
Charles	0	0
Frederick	0	0
Harford	0	0
Howard	25.24	19.22
Montgomery	0	0
Prince George's	80.67	21.44
Totals	306.9	151.2

- **Sponsor-a-Highway Program** – SHA also has a program that allows corporate sponsors to sponsor one-mile sections of Maryland roadways. The Sponsor enters into an agreement with a Maintenance Provider for litter and debris removal from the sponsored segment.

  Sponsor-A-Highway was not available in Carroll, Charles, Frederick, Harford, and Montgomery Counties as of September 30, 2009. As of October 1, 2009, routes have been added to the Sponsor-A-Highway program through all counties in MD. See Table 1-12 for numbers of currently sponsored miles.

- **Partnership Planting Program** – SHA develops partnerships with local governments, community organizations and garden clubs for the purpose of beautifying highways and improving the environment. Community gateway plantings, reforestation plantings, streetscapes and highway beautification plantings are examples of the types of projects that have been completed within the Partnership Planting Program. Table 1-13 lists the numbers of plants, counties of participation and numbers of volunteers for the last reporting period.

Table 1-13 Partnership Planting Program

County	No. Trees/Shrubs	No. Volunteers
Anne Arundel	45	10
Baltimore City	23	N/A*
Harford	22	7
Howard	481	58
Prince George's	156	16
Totals	787	91

* Earth Day planting completed in front of the SHA headquarters building by SHA staff volunteers.

- **Transportation Enhancement Program** – SHA Administers the Federal Highway Transportation Enhancement Program (TEP) for the State of Maryland. In this capacity, SHA looks for opportunities to share the potential benefits of applying for funding under this program with projects that fall under the eligible funding categories.

For potential projects that fall under the funding category 'Mitigation of Water Pollution due to Highway Runoff', SHA Highway Hydraulics Division takes the initiative with watershed groups, local municipalities, community groups and counties to encourage their participation in this program. SHA provides assistance to potential project sponsors by advising on proposal content, reviewing drafts and then providing guidance on Federal Aid requirements for construction document preparation and advertisement process.

A supported project this last year is the Westminster High School SWM Facility being undertaken by Carroll County. This project involves conversion of a failed sediment basin to a surface sand filter. The surface sand filter facility will provide water quality volume (WQ_v), recharge volume (Re_v), channel protection volume (Cp_v) and overbank flood protection volume (Q_p) for a 115 acre drainage area.

- **Roadside Debris/Safety Campaign TEP Project** – The litter campaign that was developed and reported on in the previous annual reports is completed. However, the SHA Office of Communications is developing another litter campaign to address concerns from the Governor for litter along Maryland Roadways. This new campaign will look at performing research to develop the most effective target audience and then develop a plan for media coverage to reach that audience. This effort was initiated in May 2008 and will be pursued over the next few years.

- **The 2009 Maryland Bay Game** – SHA participated as a contributor.

E.6.b Environmental Stewardship by Employees

SHA continues to provide environmental awareness training to its personnel and is committed to continuing these efforts in the future. We have provided updated data for these efforts through the following training programs below:

- **SHA Recycles Campaign** – In support of the SHA Business Plan, the Environmental Compliance and Stewardship Key Performance Area launched the SHA Recycles Campaign on April 22, 2008 to raise awareness and encourage change in consumer culture throughout the organization. The goal of this campaign is to reduce waste and litter by making conservation a priority, reusing what we previously discarded, and recycling as much as possible. The SHA Recycles Campaign is working to build a consortium of stakeholders across the entire SHA organization towards this collective goal. The campaign encourages all employees to give feedback on what can be done to save energy and fuel, reduce or eliminate waste, improve current recycling efforts, or change business practices to conserve resources. It provides education and outreach through displays and presentations at SHA events such as the Annual Earth Day Celebration, and office-wide Training and Recognition Days.

A new State-wide Recycling Task Force has been formed to examine key issues in recycling and identify ways to improve the SHA Statewide Recycling Program. SHA is continuing its pilot study on the cost-benefit of wind energy and will begin construction of a 1.8 kilowatt wind energy system at the Westminster Maintenance Shop in May 2009.

Maryland Roads 'Green' Issue

- **Reuse, Reduce Recycle Article** – The SHA *Maryland Roads* publication featured ways employees can be environmental stewards in an article called ‘Reuse, Reduce Recycle’. Included was information concerning erosion and sediment control, recycling, Potomac watershed cleanup and other information on how our reduction of waste loads can benefit the environment and provide raw materials for new products.

REUSE REDUCE RECYCLE

Although recycling is an essential part of being "green," it is only one of three very important ways to protect our environment and preserve natural resources. We should remember the 3 R's – reuse, reduce and recycle – when adapting a green lifestyle. By finding creative ways to reuse products or purchase products made from recovered materials, and by taking simple steps to reduce your daily energy consumption and the release of pollutants, you can become a major force in the fight against waste.

SAVE SOME PAPER TODAY: GET YOUR PAY STUB ON-LINE.

Join 23,000 other State employees who access their pay stubs on-line at Central Payroll Bureau's web site (http://compnet.comp.state.md.us/cpb). Follow the easy directions at the Payroll Online Service Center (Click on the red POSC symbol) and enjoy these benefits:

- Secured access
- Online pay stub history (12 rolling months)
- Up to 5 years history
- Retrieve / print W2 information (3 years history)
- Address update capability
- Direct Deposit authorization for changes
- W-4 Withholding changes

DAN ANDREWS' TOP 5 HOME ENERGY SAVERS

By Dan Andrews, Office of Plats and Surveys

1. Replace incandescent bulbs with compact fluorescent bulbs (CFLs). CFLs use about 25 percent of the energy that traditional incandescent bulbs use.
2. Adopt behavior changes – if no one is in the room, turn the lights off.
3. Dry your clothes on a clothesline.
4. Properly insulate and eliminate leaks in your home.
5. Eliminate phantom loads or leaking electricity. This refers to the electric power consumed by an appliance or device when the device is turned off or in standby mode. Such devices usually offer remote controls, digital clock features or use power adaptors. (Think computers, cell phone chargers, TVs and DVD players – this can easily be 5 percent of your electrical bill each month.)

5 REASONS TO RECYCLE

By Teri Soos, Office of Highway Development

1 SAVES NATURAL RESOURCES

Americans throw away enough aluminum to rebuild our entire commercial fleet of airplanes every 3 months.

The average American uses seven trees a year in paper, wood, and other products. This amounts to about 2,000,000,000 trees per year.

2 SAVES ENERGY

The energy saved each year by steel recycling is equal to the electrical power used by 18 million homes each year - or enough energy to last Los Angeles residents for eight years.

Recycling plastic saves twice as much energy as burning it in an incinerator.

3 SAVES CLEAN AIR AND WATER

Recycling glass instead of making it from silica sand reduces mining waste by 70 percent, water use by 50 percent, and air pollution by 20 percent.

Each ton of recycled paper can save 17 trees, 380 gallons of oil, three cubic yards of landfill space, and 7000 gallons of water. This represents a 58 percent water savings and 60 pounds less of air pollution.

4 SAVES LANDFILL SPACE

About 80 percent of what Americans throw away is recyclable, yet our recycling rate is just 28 percent.

Every year, each American throws out about 1,200 pounds of organic garbage that can be composted.

5 SAVES MONEY AND CREATES JOBS

On average, it costs $30 per ton to recycle trash, $50 to send it to the landfill, and $65 to $75 to incinerate it.

The Washington, DC-based Institute for Local Self-Reliance calculates that recycling creates 36 jobs per 10,000 tons of material recycled compared to 6 jobs for every 10,000 of tons brought to traditional disposal facilities.

The Alice Ferguson Foundation sponsors an annual trash cleanup of the Potomac Watershed. In April, more than 12,000 volunteers removed 285 tons of garbage from the shores of the Potomac River, 27 tons of which were recyclable glass, aluminum and plastic. The top brand names reported were 7-Eleven, McDonalds, Coca-Cola, Budweiser/Bud-lite, & Pepsi. This listing highlights some of the more remarkable items removed during the effort. Take a look at this list and make note of the things that can be reused or recycled. Please remember to recycle or dispose of trash properly!

- 13,596 plastic bags
- 1,309 tires
- 40 shot gun shells
- 35 shoes
- 28 shopping carts
- 27 bicycles
- 23 metal and plastic barrels
- 20 diapers
- 7 propane tanks
- 7 toilets
- 6 bras
- 6 carpets
- 6 crab pots
- 5 refrigerators
- 5 televisions
- 4 bed frames
- 1 bathtub
- 3 double beds
- 3 lawn mowers
- 3 skateboards
- 3 Tiki torches
- 2 computers
- 2 queen mattresses
- 2 sleeping bags
- 1 American flag
- 1 bowling ball
- 1 foam finger
- 1 machete
- 1 prosthetic leg
- 1 trampoline
- 1 animal cage
- 1 unopened jar of pickles
- CD case full of rap music
- 1 driver's license
- 1 duffel bag with 24 unopened beer bottles wrapped in 2 towels
- Ethiopian dollar bill (1 birr)
- 1 full bottle of motor oil
- 1 full-length Mirror
- half a canoe
- message in small bottle with phone number on it
- pharmaceutical medicines
- Port-a-Potty
- Presidents Clinton and Newt Gingrich dolls
- Russian Identification Card
- 100 lb. safe
- backpack containing wallet and clothes
- 4 Easter eggs filled with money

4 MARYLAND ROADS

ESC EXPRESS: STOPPING DIRT IN ITS TRACKS

By Steve Buckley, OHD Highway Hydraulics

Question: What is short, black, and seemingly everywhere a 'drawn' into the dirt? Why of course, it's silt fence, the ubiquitous sediment control that lines almost every project. But silt fence is only a small part of SHA's extensive erosion and sediment control effort. Along with construction techniques, design plans and specifications, a crucial part of that effort is the three part training that SHA provides to our personnel and customers.

Required by State Law for responsible personnel involved in grading and earth disturbing activities, the initial training provided is the MDE Responsible Personnel Training or "Green Card." This session provides a basic overview of the law and an introduction to the various controls used.

The second part of the trilogy is the SHA Basic Erosion and Sediment Control Training for Inspectors and Contractors (BEST) which most refer to as "Yellow Card." This training is required for Contractor's Erosion and Sediment Control Managers (ESCM) and Superintendents working on SHA construction projects as well as SHA inspection personnel.

The third leg is the Designer's Certification. Effective January 2009, all designers of SHA erosion and sediment control plans must be certified.

All this training, a collaborative effort between the Office of Construction and Office of Highway Development, could not happen without the dedicated efforts of **Don Hoey** (OOC) and **Polly Solliday** (OHD). Don and Polly have worked to refine the training modules into efficient, informative sessions that provide the necessary information, training, testing and certification. Don has been with SHA as the OOC Environmental Manager for only two years but has worked as part of SHA's Quality Assurance Program for over two decades and is an active member of the International Erosion Control Association. Polly is a civil engineering graduate of the University of Maryland and has been with the Highway Hydraulics Division since 1995 and has been active in the QA Programs for the last four years. Since its beginning in 2004, over 2000 people have obtained certification through the program.

The training is provided monthly through the Maryland Highway Contractors Association (MHCA) and by arrangement with Polly through your unit training coordinator.

MILK JUG TODAY, FLOOR TILES TOMORROW

In 1988 the Society of Plastics Industry Inc. introduced the resin identification coding system (the number found inside the triangle formed by 3 arrows) to allow for easier identification of different types of plastics. This code, often found on the bottom of plastic products, indicates the polymer type that recycling plants use for collecting, cleaning and reprocessing. This chart shows what that plastic bottle you recycled today will turn into tomorrow.

Code	Original Application	Recycled into
#1	drink bottles, peanut butter jars, microwavable food trays	Fiber for carpet, fleece jackets, comforter fill, tote bags
#2	milk jugs, laundry detergent bottles, cereal box liners, wire and cable covering	motor oil and antifreeze bottles, deck lumber, floor tiles, crates, flower pots
#3	blister packs and clamshells, window frames, medical tubing, carpet backing	mud flaps, cassette trays, traffic cones, garden hose, loose-leaf binders
#4	dry cleaning bags, coating for milk cartons, toys, squeezable bottles	shipping envelopes, garbage can liners, furniture, landscape timber
#5	yogurt and margarine containers, medicine bottles, syrup bottles	brooms & brushes, bicycle racks, garden rakes, auto signal lights
#6	cups, plates, packing peanuts, CD cases, aspirin bottles, coat hangers, toys	insulation, thermometers, rulers, license plate frames
#7	oven-baking bags, barrier layers, custom packaging	bottles and plastic lumber

Source: American Chemistry Council

Want Information on Recycling?

Visit **www.mdrecycles.org** - Maryland's official recycling site for government, business and homeowners. It lists curbside recycling information for every county and Baltimore City, as well as a directory of every recycler known to be operating in Maryland, for items not covered in curbside recycling programs. Also listed are sites where items can be donated to be reused, many of which qualify for tax deductions.

MARYLAND ROADS 5

Maryland Roads Features Environmental Stewardship by Employees in the Spring 2009 Issue

- **SHA Environmental Ethic Project** – In 2008, the Advanced Leadership Program (ALP) Class of 2009 began work on initiating an SHA Environmental Ethic at the State Highway Administration. Part of this initiative included administering an environmental awareness survey to all employees as well as to our partners. This survey was presented to employees during late fall, 2008, and to the consultant and contracting community during the Maryland Quality Initiative (MdQI) conference held in Baltimore in February 2009. During day two of the MdQI conference, the ALP class also provided a luncheon skit and presentation focusing on our moral duty as an agency to be a leader in environmental responsibility.

  The ALP Class also had a booth at the SHA Earth Day event in April 2009. Fun trivia information and facts about what individuals could do reduce their energy usage and carbon footprint were presented to attendees.

  In the spring of 2009, the ALP class took the results of the employee surveys and developed an outline for a mandatory Environmental Awareness Training to be provided by Senior Managers at their Training and Recognition day. Each office went over the results of their survey, viewed a thought-provoking presentation, and had an open discussion of items they could undertake to help reduce their overall impact on the environment. Ultimately, each team, of approximately 12 employees, in each office and district will have committed to an action plan for one of the items discussed. Additionally, managers are expected to put an environmental stewardship goal in their FY2010 performance plan. The

ALP class will be preparing a summary of these action items this fall as part of their class project.

Other initiatives underway are recurring emails to SHA employees with environmental facts and ideas, a poster campaign, and the Green Ideas Program which will be a forum for employees to present their ideas and potentially receive assistance in bringing those ideas into the SHA way of doing business.

DPSCS inmates planting trees at the Driver Road site within Patapsco Valley State Park Spring 2009

- *New!* **Million Tree Initiative** – In the fall of 2008, the Maryland State Highway Administration (SHA), the Maryland Department of Natural Resources (MDNR), Federal Highway Administration (FHWA), and the Maryland Department of Safety and Correctional Services (DPSCS) formed a partnership to plant trees along Maryland roadsides and in State right-of-way. The tree-planting program directly supports Governor Martin O'Malley's *Smart, Green and Growing* Initiative. SHA is funding the trees and materials; MDNR is funding the labor, which is provided by inmates from DPSCS. As of May 30, 2009 over 152,000 trees have been planted and 38,300 tree shelters installed to protect saplings from deer intrusion. Trees are being planted during spring and fall months so they can survive hot, dry summers and harsh winters.

  Funds for the purchase of the trees, support stakes and tree shelters are made possible from the FHWA Transportation Enhancement Program (TEP). The total TEP funding and match for the SHA participation in the *One Million Tree* Initiative is $800,000, which will provide funding through 2011.

- **Performance Excellent Training Conference (PETC) –** The Highway Hydraulics Division's (HHD) Erosion and Sediment Control (ESC) program sponsored an exhibit at the SHA PETC held on November, 21 2008 in College Park, Maryland. This conference is hosted annually by SHA senior management and is attended by hundreds of SHA employees from all districts. The purpose of the conference is to recognize areas of improvement in processes that result in increased performance excellence.

  The SHA Highway Hydraulics Division 2008 exhibit focused on the ESC Quality Assurance Toolkit (QA Toolkit) that was developed by SHA Highway Hydraulics Division, SHA Design Technical Services Division (DTSD) and the consulting firm Ram Corporation. The QA Toolkit is a web-based system utilizing wireless tablet computers for field inspectors. The purpose of the QA Toolkit is to reduce the time it takes for ESC construction inspection data to flow from the construction quality control inspector, who collects the data in the field, to the design office that needs to receive and process the data for decision making and reporting. A secondary purpose is to eliminate transcription errors during the process used to transmit the data. Additional information concerning specifics of this tool is included under Section E.2.a, above.

HHD PETC Exhibit Featuring ESC QA Toolkit, Ranjit Sahai and Don Hoey

- **SHA Environmental Advisory Committee** – A committee was formed by SHA in order to seek expert level, environmental advice from pronounced experts and practitioners in various fields and industries. This committee meets several times a year to advise SHA senior management on initiatives ranging from clean air, wind power, water quality and recycle/reuse. Mr. Steve Pattison, of MDE, sits on this committee.

- **Graduate Engineers Training Program (GETP)** – This two-year program provides training to all new SHA engineers and includes training concerning the MEPA/NEPA and Environmental Permitting. In 2009, 77 individuals attended these modules including 26 participants who successfully completed the program on August 20, 2009.

- **OHD University** – This is an annual, internal training program for the Office of Highway Development that provides technical training for new engineers and others who desire to take refresher courses. In addition to highway engineering and technical issues, detailed information is presented for SWM, ESC and environmental permitting issues, including NPDES concerns. The number of people trained during 2009 was 28.

- **Statewide Pesticide/Vegetation Management Training** – There are several types of internal training sessions for pesticide management that SHA provides annually. They include re-certification, right-of-way pre-certification, aquatic pre-certification, herbicide update and an annual vegetation management conference. The numbers of participants at each of these training sessions are listed in Tables 1-14 to 1-17

Table 1-14 Pesticide Applicator Training (ENV100)

SHA District	Number Trained
3 (MO, PG)	17
4 (BA. HA)	17
5 (AA, CH)	7
7(CL,FR, HO)	15
Totals	56

Table 1-15 SHA Vegetation Management (Re-certification) Conference (ENV200)

SHA District	Number Trained
3 (MO, PG)	8
4 (BA. HA)	22
5 (AA, CH)	14
7(CL,FR, HO)	0
Totals	44

Table 1-16 Pesticide Core and Right-of-Way Pre-Certification (ENV210)

SHA District	Number Trained
3 (MO, PG)	0
4 (BA. HA)	0
5 (AA, CH)	20
7(CL,FR, HO)	1
Totals	21

Table 1-17 Pesticide Aquatic Certification (ENV600)

SHA District	Number Trained
3 (MO, PG)	17
4 (BA. HA)	17
5 (AA, CH)	7
7(CL,FR, HO)	15
Totals	56

- **Annual Vegetation Management Conference –** The annual conference is sponsored by the Office of Environmental Design and the Maryland SHA Statewide Vegetation Management Team. It provides a forum for disseminating current information on topics such as invasive species eradication, nutrient management, stormwater management facility vegetation management, turf establishment, forest conservation, native meadow establishment, and herbicide application. Each SHA maintenance shop sends people to these conferences. The 2009 conference was held on October 21, 2009 and numbers of attendees was anticipated to be more than 55.

- **Environmental Awareness Training (Chesapeake Bay Field Trips)** – This training is provided to all new employees. These field trips demonstrate the link between highway runoff and its impact on streams, rivers and on the health of the Chesapeake Bay. During the last reporting period, 4 classes were held with 75 people attending.

- **Maryland Department of Transportation (MDOT) Water Quality Policies and Water Quality Clearing House Web Page** – This is a continuing effort that provides information on department-wide water quality policies and other regulations applicable to transportation projects. This webpage is periodically updated with regulatory/policy changes and can be accessed at www.mdot.state.md.us and clicking on the Water Quality Clearinghouse link toward the bottom of the page.

- **Environmental Permitting Training Tour** – Biennially the SHA headquarters environmental offices including Environmental Planning, Highway Hydraulics Division, Environmental Programs Division, Landscape Architecture Division, Landscape Operations Division, and Cultural Resources Group, provide training on environmental permitting requirements. This training is given to all levels of district office personnel including maintenance, construction inspection and special projects design. The training is also given to headquarters' personnel including construction, right-of-way, design divisions, access permits and project planning. It has also been added as a module in the Office of Highway Development University (OHDU) series of training classes.

  The goal of the training is to provide all SHA personnel with an understanding of environmental resources and requirements for avoiding and minimizing impacts, mitigating and obtaining permits. The training also details procedures and provides contacts for answering questions and assisting in processing information. Specific topics covered by the training are:

  - NEPA/MEPA Processes;
  - Cultural Resources;
  - Environmental Justice;
  - Wetlands, Waterways, FEMA and other water resources;
  - NPDES Construction Permit, MS4 Phase I and Phase II Permits, Industrial Permits;
  - SWM & ESC;
  - Forest Conservation, Reforestation and Roadside Tree Law;
  - Scenic Highways Initiative;
  - Environmental Compliance for SHA-owned Facilities.

  This training was during the previous reporting period, and because it is held every two years, no training was held during this reporting period.

- **Employee Commuter Reduction Incentives** – SHA offers several incentives to reduce the number of drivers and/or number of commuter days/miles per week by Administration employees. Fewer commuter days and miles mean less vehicle pollutants entering the watershed.

  Alternate work schedules include flexible work hours allowing employees to work compressed workweeks reducing the total number of commuting days and miles.

  Telecommuting allows employees to work from a remote location (presumably at or close to home) and also reduces the number of commuting days and miles per week. Each office has or is developing a teleworking policy.

  Car-pooling has been encouraged at SHA for many years and reduces the number of commuters on the road. SHA car-pooling incentives include prioritizing parking space allocation to those in a designated car pool and Administration assistance in locating a carpool within the employee's residential area through parking database.

  Finally, employee ID badges allow free access to MTA mass transit including the Baltimore area subway, light rail and buses. This encourages the use of mass transit by SHA employees who live within the Baltimore area.

- **SHA Vehicle and Equipment Idling Policy** – On September 22, 2009, the SHA Administrator, Neil Pedersen, issued a policy regarding idling of engines for state equipment and vehicles. The purpose is to reduce fuel consumption by state forces, and if adhered to, will result in pollutant load reduction as well.

F Watershed Assessment

The watershed assessment effort described by the permit includes continuing to provide available geographic information system (GIS) highway data to permitted NPDES municipalities and MDE; completing the impervious surface accounting by the fourth annual report; retrofitting impervious areas with poor or no control infrastructure; and working with NPDES municipalities to maximize water quality improvements in areas of local concern.

F.1 GIS Highway Data to NPDES Jurisdictions and MDE

SHA continues to make all GIS highway data available to NPDES jurisdictions and MDE.

We coordinated with the MDE Science Services Administration on data issues. This meeting

F.2 Complete Impervious Accounting by Fourth Annual Report

SHA will complete the Impervious Accounting by the fourth annual report, October 2009. See the work plan and schedule included in the discussion in Section C.3, Impervious Surface Account, above.

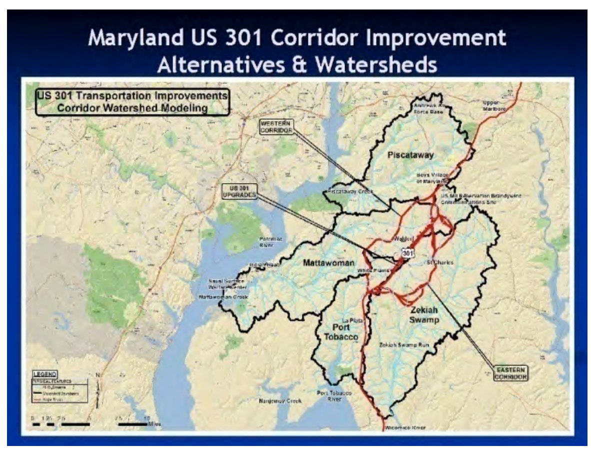
F.3 Impervious Area Retrofits

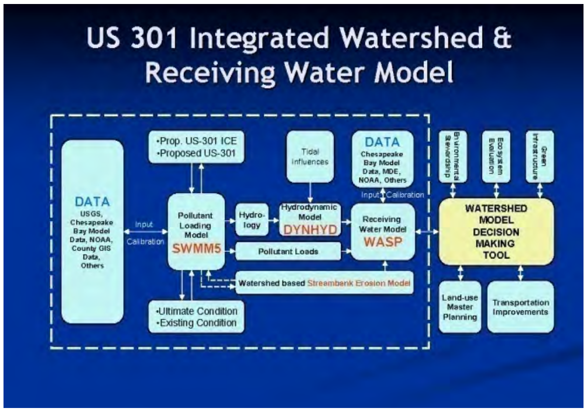
As we progress in the impervious area accounting process described in Section C.3, we will be identifying sites that prove suitable for developing as stormwater facilities to treat additional impervious surfaces in these counties. These efforts will be coordinated within a watershed, tributary strategy, Tier II stream anti-degradation and TMDL perspective.

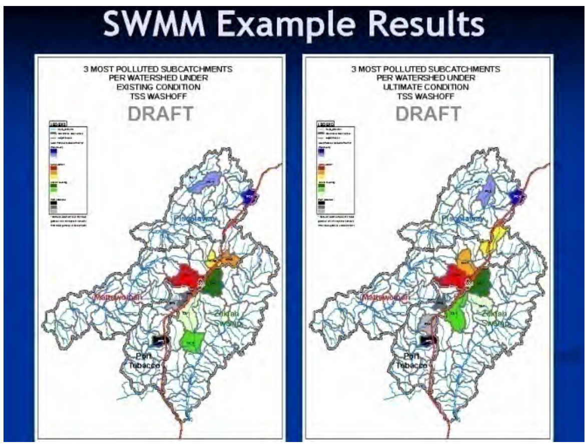
Additionally, as part of our Water Quality Banking Agreement with the MDE Sediment and Stormwater Division, SHA is actively pursing locating water quality retrofit sites in areas with poor or no runoff control infrastructure. A site search has been completed for the Patuxent River Area (02-13-11) and fourteen sites in Howard and Prince George's Counties have been identified. We are in the process of selecting sites to place into a design project.

F.4 Maximize Water Quality Improvements in Areas of Local Concern

Because SHA is not a land planning and zoning entity, we do not have the authority or ability to generate and carry out priorities for individual watersheds. As part of this permit condition, MDE is requiring that we not only implement restoration efforts, but that we adhere to the watershed restoration goals and priorities established by local NPDES jurisdictions.







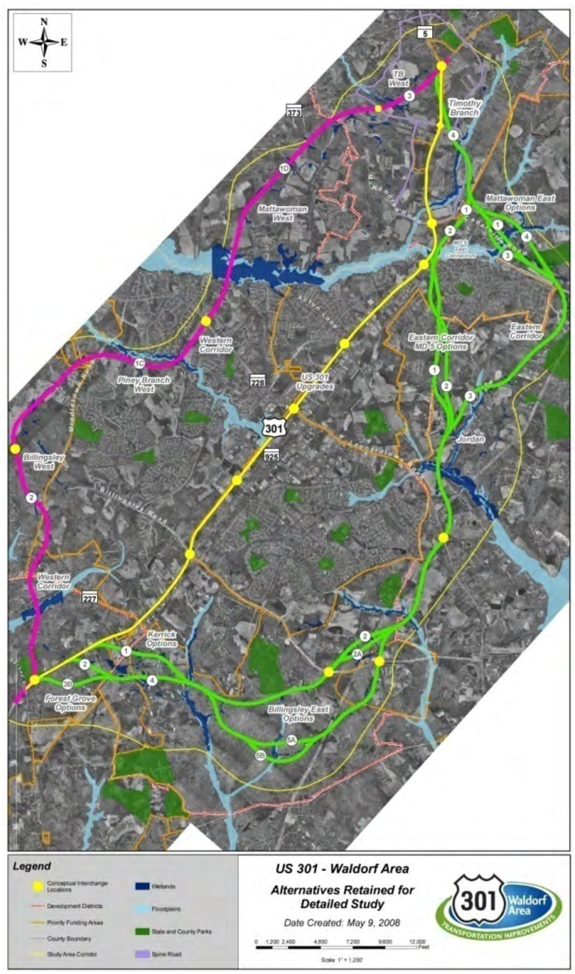
Presentation Slides from the US-301 Watershed Modeling Study

US-301 Watershed-Based SWM Assessment

A component of the Green Highways Initiative is to develop US 301, or a bypass alternative, as a green highway. This entails assessing the watershed-level impacts of all potential options. Methodologies for modeling water quality assessments for NEPA reporting were investigated using *NCHRP 25-25 Task 35, Water Quality Analyses for NEPA Documents: Selecting Appropriate Methodologies*, and a model was developed for the US 301 corridor alternatives. Pollutant loadings for existing and ultimate watershed development conditions will be evaluated for each alternate. Pollutants to be studied in the model include:

- Nutrients
  - Total Phosphorus (TP)
  - Ortho-Phosphorus (PO4)
  - Nitrite/Nitrate (NO2/NO3)
  - Total KjeldahlNitrogen (TKN)
  - Ammonia (NH3)
  - Total Organic Nitrogen (TON)
- Metals
  - Copper
  - Zinc
  - Cadmium
  - Lead
- Bacteria
  - Biochemical Oxygen Demand (BOD)
  - Chemical Oxygen Demand (COD)
  - Fecal Coliform
- Total Suspended Solids (TSS

The study is also taking into consideration Maryland's Green Infrastructure initiative. Due to recent budget cuts, further work on this study has been postponed.



Retained Alternatives for the US 301 Project

EPA Green Highways Grant – Framework for Watershed Based SWM

During the last year, SHA continued work on the grant from EPA to develop a framework to implement a watershed-based approach to stormwater management as part of the Green Highways Partnership. The Green Highways Partnership connects diverse partners from all aspects of highway the infrastructure life cycle, from the design, construction, and maintenance to the governmental regulation and community outreach, and includes the EPA, SHA, and FHWA as key partners.

In the watershed-approach study, SHA is examining ways to implement a common watershed decision-making process within SHA, local jurisdictions, and regulatory agencies. The primary focus of the study centers on transportation-related projects, however it is possible that the framework developed may have a wider range of applicability since the study views the watershed holistically when planning and implementing stormwater management. The study emphasizes watershed restoration and preservation above-and-beyond regulatory and NPDES requirements while simultaneously promoting elements of green infrastructure.

During the first year of the study, SHA completed a literature and data review and compiled summaries of each document. The literature review was performed to determine how other frameworks have been developed as well as to determine if any previous work with watershed management have been performed, to what degree, and to what success level. A draft flow-chart has also been developed, demonstrating the task flow necessary to allow watershed-based stormwater management plans to work within the context of the SHA process. This has allowed SHA to examine items that may already be in place to implement the framework as well as areas which SHA must modify the internal policy to adopt the framework.

SHA also completed an examination of four major case studies. These case studies involve partnerships between SHA, local governments, and regulatory agencies, to develop watershed-based management plans for several major highway projects. The case studies revealed several areas which proved effective, while other areas fell short of expectations. The successful areas will be incorporated into the framework and the areas of improvement will feature options for increase effectiveness.

During the second year of the study, SHA began drafting the framework. The document explains the mission of the GHP, the watershed approach, and compares highway project needs as well as watershed needs, and how to assemble the information. Examples include accountability tracking, credits and trading, and ultimate ownership.

During the third year of the study, the framework became more detailed and robust. A new comparison of traditional approaches and green highway approaches were examined and included in the framework. Suggestions on how to rank priorities of metrics, including associated cost-benefits analysis are also illustrated.

Also, during the third year, a scope change to the required deliverables was authorized by EPA. Rather than creation of a single document, two will be developed. One will explain the framework and how it can be implemented; the other will be more technical and explain how the framework has developed, including the literature search, gap analysis and recommendations for future study. Fact sheets will also not be developed to better disseminate information quickly in preparation for anticipated widespread publication, internet education, formal presentations and other outreach purposes. The EPA granted an additional one year extension to complete the work.

G Watershed Restoration

Requirements for this permit condition include developing and implementing twenty-five significant stormwater management retrofit projects, contributing to local watershed restoration activities by constructing or funding retrofits within locally targeted watersheds, and submitting annual reports on watershed activities that contain proposals, costs, schedules, implementation status and impervious acres proposed for management.

G.1 Implement 25 Significant SWM Retrofit Projects

Previously, SHA has reported on fifty-two projects either to retrofit older, failing stormwater BMPs or to enhance or stabilize reaches of streams. These projects are nearly completion.

After a conversation with the MDE NPDES program manager and staff, SHA realized that the credit for future 'treated impervious' for reporting percentages in permit compliance is taken solely from these 'restoration credits' rather from the overall amount of impervious pavement that SHA treats on the roadway system. With that in mind, we are reviewing our past efforts and revisiting the number and type of projects we have actually completed since 2005 that would qualify as restoration credit. These are projects that were developed outside of roadway development stormwater management requirements and consist of upgrading stormwater BMPs to current regulations, stream stabilization and restoration, and outfall stabilization projects. This list of additional projects has been added to our current list, increasing the number of projects under develop or completed to 105. See Table 1-18 for the current list of watershed restoration projects. The overall acreage of restoration credit for impervious treated increases to 671.02 acres with the addition of these projects. Although some projects may not warrant 100% credit due to varying levels of upgrades or pollutant removal capabilities, we have included the total amount of imperviousness currently draining to and being treated by the practice. Efficiencies may be negotiated with MDE in the future.

In other words, SHA has moved beyond the requirement of 'twenty-five significant projects' to quantify our actual efforts in providing restoration credit. As we continue this evaluation of past restoration projects, we will be adding new projects to the list. Documentation in the form of construction plans for these additional projects can be provided to MDE at their request.

The database for Table D from Attachment A of the permit is included on the attached CD and includes these additional projects.

Table 1-18 Watershed Restoration Projects

Projects by Watershed	Retrofit Type	Status	Restored Impervious Acres
Lower Susquehanna River – 02-12-02			
1. BMP 120076	BMP retrofit	Complete	2.82
Chester River Area – 02-13-05			
2. BMP 170011*	BMP retrofit	Design	0.41
3. BMP 170012*	BMP Retrofit	Design	0.23
Bush River Area – 02-13-07			
4. BMP 120069	BMP Retrofit	Complete	4.16
5. BMP 120072	BMP Retrofit	Complete	4.68
6. BMP 120073	BMP Retrofit	Complete	3.99
7. BMP 120075	BMP Retrofit	Complete	1.77
8. BMP 120081	BMP Retrofit	Complete	2.39
9. BMP 120082	BMP Retrofit	Complete	1.00

Table 1-18 Watershed Restoration Projects

Projects by Watershed	Retrofit Type	Status	Restored Impervious Acres
Gunpowder River – 02-13-08			
10. I-83 Outfall Stabilization of Tributaries to Gunpowder Falls	Stream	On-Hold	7.85
Patapsco River – 02-13-09			
11. BMP 020120	BMP Retrofit	Complete	17.73
12. BMP 020121	BMP Retrofit	Complete	0.96
13. BMP 020122	BMP Retrofit	Complete	0.92
14. BMP 020625*	BMP Retrofit	Design	2.46
15. BMP 030281	BMP Retrofit	Complete	8.35
16. MD 139 Tributary to Towson Run Stabilization	Stream Stabilization	Complete	260.30
17. BMP 020111	BMP Retrofit	Complete	6.04
18. BMP 020112	BMP Retrofit	Complete	0.56
19. BMP 020098	BMP Retrofit	Construction	0.68
20. BMP 020099	BMP Enhancement	Construction	0.75
21. BMP 020476	BMP Retrofit	Construction	3.79
22. BMP 020477	BMP Retrofit	Construction	Combined with 020476
23. BMP 130197*	BMP Retrofit	Complete	0.44
24. BMP 130207*	BMP Retrofit	Complete	1.57
25. BMP 130221*	BMP Retrofit	Complete	0.17
26. BMP 130210*	BMP Retrofit	Complete	0.24
27. BMP 130217*	BMP Retrofit	Complete	0.10
West Chesapeake Bay – 02-13-10			
28. BMP 020019	BMP Retrofit	Construction	1.22
29. BMP 020022	BMP Retrofit	Complete	1.06
30. BMP 020027	BMP Retrofit	Complete	1.59
31. BMP 020029	BMP Retrofit	Complete	0.88
32. BMP 020031	BMP Retrofit	Complete	2.29
33. BMP 020088	BMP Retrofit	Complete	3.53
34. BMP 020481	BMP Retrofit	Complete	2.09
35. BMP 020522	BMP Retrofit	Complete	1.70

Table 1-18 Watershed Restoration Projects

Projects by Watershed	Retrofit Type	Status	Restored Impervious Acres
36. BMP 020273	BMP Retrofit	Construction	1.18
37. BMP 020491	BMP retrofit	Complete	1.79
38. BMP 020185	BMP Retrofit	Construction	0.48
39. BMP 020198	BMP Retrofit	Construction	0.68
40. BMP 020201	BMP retrofit	Construction	1.01
41. BMP 020205	BMP Retrofit	Construction	1.16
42. BMP 020206	BMP Retrofit	Construction	0.49
43. BMP 020210	BMP Retrofit	Construction	0.36
44. BMP 020220	BMP Retrofit	Construction	0.72
45. BMP 020258*	BMP Retrofit	Design	3.27
46. BMP 020260*	BMP Retrofit	Design	1.41
47. BMP 020268*	BMP Retrofit	Design	7.08
48. BMP 020393*	BMP Retrofit	Design	4.35
49. BMP 020394*	BMP Retrofit	Design	3.27
50. BMP 020014*	BMP Retrofit	Design	2.20
51. BMP 020015*	BMP Retrofit	Design	1.22
52. BMP 020016*	BMP Retrofit	Design	0.95
53. BMP 020017*	BMP Retrofit	Design	0.44
54. BMP 020018*	BMP Retrofit	Design	0.89
Patuxent River – 02-13-11			
55. BMP 160059	BMP Retrofit	Complete	3.2
56. BMP 020488	BMP Retrofit	Complete	5.56
57. BMP 160217	BMP Retrofit	Complete	0.64
58. BMP 160219	BMP Retrofit	Complete	0.91
59. BMP 160380	BMP Retrofit	Complete	3.42
60. Unnamed Tributary to Rocky Gorge Reservoir adjacent US 29	Stream Stabilization	Cancelled	
61. BMP 020301*	BMP Retrofit	Design	2.30
62. BMP 020311*	BMP Retrofit	Design	0.28
63. BMP 020437*	BMP Retrofit	Design	4.13
64. BMP 130149*	BMP Retrofit	Complete	0.48
65. BMP 130150*	BMP Retrofit	Complete	1.02

Table 1-18 Watershed Restoration Projects

Projects by Watershed	Retrofit Type	Status	Restored Impervious Acres
66.BMP 130154*	BMP Retrofit	Complete	0.47
67.BMP 130159*	BMP Retrofit	Complete	0.02
68.BMP 130160*	BMP Retrofit	Complete	0.52
69.BMP 130162*	BMP Retrofit	Complete	0.66
70.BMP 130179*	BMP Retrofit	Complete	2.10
71.BMP 130180*	BMP Retrofit	Complete	0.43
72.BMP 130187*	BMP Retrofit	Complete	0.13
73.BMP 130188*	BMP Retrofit	Complete	0.12
74.BMP 130189*	BMP Retrofit	Complete	0.03
75.BMP 130190*	BMP Retrofit	Complete	0.03
76.BMP 130191*	BMP Retrofit	Complete	0.05
77.BMP 130192*	BMP Retrofit	Complete	0.05
78.BMP 130193*	BMP Retrofit	Complete	0.10
79.BMP 130194*	BMP Retrofit	Complete	0.22
80.BMP 130232*	BMP Retrofit	Complete	0.03
81.BMP 130242*	BMP Retrofit	Complete	0.72
82.BMP 130243*	BMP Retrofit	Complete	3.49
83.BMP 150228*	BMP Retrofit	Complete	0.13
84.BMP 150331*	BMP Retrofit	Complete	0.23
85.BMP 130047*	BMP Retrofit	Complete	1.39
Lower Potomac River – 02-14-01			
86.BMP 160456	BMP Retrofit	Completed	1.70
87.BMP 080014*	BMP Retrofit	Construction	0.24
88.BMP 050039*	BMP Retrofit	Construction	0.10
89.BMP 080040*	BMP Retrofit	Construction	0.10
90.BMP 080041*	BMP Retrofit	Construction	0.12
91.BMP 080042*	BMP Retrofit	Construction	0.11
92.BMP 080043*	BMP Retrofit	Construction	0.28
93.BMP 080044*	BMP Retrofit	Construction	0.20
94.BMP 080083*	BMP Retrofit	Construction	0.06
95.BMP 080095*	BMP Retrofit	Construction	0.48
Washington Metropolitan-02-14-02			
96.BMP 160607	BMP Retrofit	Complete	0.41

Table 1-18 Watershed Restoration Projects

Projects by Watershed	Retrofit Type	Status	Restored Impervious Acres
97. BMP 160609	BMP Retrofit	Complete	Combined with 160607
98. BMP 160653	BMP Retrofit	Complete	15.80
99. Long Draught Branch Restoration/ Stabilization	Stream Stabilization	Delayed Due to Agency Comments	228
100. BMP 150002*	BMP Retrofit	Complete	0.31
101. BMP 150003*	BMP Retrofit	Complete	1.69
102. BMP 150004*	BMP Retrofit	Complete	Combined with 150003
103. BMP 150005*	BMP Retrofit	Complete	Combined with 150003
104. BMP 150301*	BMP Retrofit	Complete	0.28
105. BMP 150362*	BMP Retrofit	Complete	1.03
106. BMP 150380*	BMP Retrofit	Complete	1.05
107. BMP 150550*	BMP Retrofit	Complete	1.26
108. BMP 150076*	BMP Retrofit	Complete	1.25
Middle Potomac River – 02-14-03			
109. Tributary to Tuscarora Creek Stabilization at US 340 and US 50	Stream Stabilization	Complete	1.94
110. BMP 150270*	BMP retrofit	Complete	0.08

* Projects added since last report.

G.2 Contribute to Local NPDES Watershed Restoration Activities

SHA often participates in and supports watershed interest groups and local jurisdictions in their activities. In addition, SHA has participated directly or indirectly in developing watershed plans as well as providing funding. The Maryland Department of Transportation's State Highway Administration oversees the Federal Transportation Enhancement Program (TEP) and encourages the use of these funds by local jurisdictions and interest groups to fund water quality projects associated with roadway runoff.

The following is a summary of watershed activities undertaken during the report period:

- **Laurel Lakes Task Force – PG County**. The SHA I-95/Contee Road project (PG419A21) lies within the Bear Branch watershed and SHA participates on this Task Force. The goal of the group is to address sedimentation issues within the watershed.

A field meeting was held July 30, 2007 to assess the SHA involvement in the watershed restoration efforts. SHA has agreed to provide monitoring equipment at the downstream side of I-95 culvert at Bear Branch in order to assess the effect our roadway project will have on the watershed. SHA will also continue to attend task force meetings, update the group on the project as it progresses and provide input on the overall watershed restoration efforts. As a member of the task force, SHA will be coordinating our stormwater design efforts with the other members including PG county and the City of Laurel.

The I-95/Contee Road project recently received design funding (after being put on hold for a number of months) and is currently scheduled for advertisement as a Design/Build contract in spring 2010. The project will be designed in accordance with the Stormwater Management Act of 2007, implementing ESD features.

- **South River Federation – AA County.** The BMP upgrade projects mentioned in the last annual report were delayed to address in-stream issues.

- **Whitehall Creek Watershed – AA County.** This is a Transportation Enhancement Program (TEP) funded project being undertaken by Anne Arundel County. SHA is supporting this project through the TEP review process and has previously recommended it for award. SHA worked with the county to prepare a watershed assessment study and actively participated in a multi-agency effort to address water quality concerns in this watershed. The project proposes construction of various stream segments at the head of the watershed as well as significant stabilization from the US 50 interchange at MD 279 up to the point of tidal influence. Currently, the project is under design by the county.

- **MD 213 Stormwater Retrofit for Gravel Run South – (Corsica River, not Phase 1)** Although not a phase I jurisdiction, the Corsica watershed is a special initiative by the Governor to implement tributary strategies and a Watershed Restoration Action Strategy (WRAS). This project is sponsored by the Town of Centreville and SHA supported funding. TEP funding was subsequently granted. Funding support was also provided by MDE through Section 319 grant initiatives.

  The project objective is to provide stormwater management treatment to a significant amount of impervious surface from MD 213. The project has progressed through the design process in 2008 and is now entering the construction phase.

G.3 Report and Submit Annually

SHA currently submits information on our watershed restoration activities including retrofit proposals, costs, schedules, implementation status and impervious acres proposed for management.

H Assessment of Controls

This condition requires that SHA develop a proposal and receive approval for a watershed restoration project by October 21, 2006; develop and receive approval for a monitoring plan that should include chemical, biological and physical monitoring according to parameters specified in the permit and submit date annually.

H.1 Restoration Site Approved by October 21, 2006

The Long Draught Branch restoration project was previously approved as our restoration site. This project has undergone difficulties in obtaining the joint permit approval for construction. SHA is investigating the possibility of altering the proposed design in order to address agency concerns and is continuing to pursue this project. However, the current budget cuts have caused us to delay construction funding until 2014. We will continue to provide monitoring on this project in accordance with the permit requirements.

H.2 Monitoring Plan

Based on the previous approval of the Long Draught Branch project by MDE-WMA, significant monitoring (physical, chemical and biological) was performed. The final report for the pre-construction monitoring data was included in the 2008 annual.

The pre-construction monitoring was completed on this project. Since the project has been delayed, the post-construction monitoring data will not be available until after the construction is completed.

In the interim, we are pursuing monitoring of a failed infiltration basin and these monitoring results are included in Appendix D.

H.3 Annual Data Submittal

Monitoring data has been included in the formats requested as Tables E and F in Attachment A of the Phase I permit. These are included on the attached CD.

I Program Funding

This condition requires that a fiscal analysis of capital, operation and maintenance expenditures necessary to comply with the conditions of this permit be submitted, and that adequate program funding be made available to ensure compliance.

Available Funding

In 2006, SHA had procured open-end consultant contracts in the amount of $9 million in order to accomplish both the current Phase I and Phase II NPDES permits. We are currently in the process of procuring additional open-ended consultant contracts in the amount of $18 million for five years to continue our efforts for the future.

In addition to the funding commitment from this office we also use State Planning and Research funds, Transportation Enhancement Program (TEP) funds and SHA Operations and Maintenance funds in completing NPDES requirements.

Required Fiscal Analysis Data

Currently, SHA tracks spending for the NPDES program as a whole and breaks out a few items such as NPDES Stormwater Facility Program and industrial activities. We do not currently track many of the requested areas such as street sweeping, inlet cleaning or database maintenance as separate expenditures.

According to our current records, the total spent for the MS4 NPDES, the Stormwater Facility Program and the Industrial NPDES are listed in Table 1-19, below.

Table 1-19 SHA Capital Expenditures for NPDES

Fiscal Year	Expenditure (Millions)
2005	$ 3.40
2006	$ 7.26
2007	$ 5.74
2008	$ 5.73
2009	$ 6.42

J Total Maximum Daily Loads

The permit states that MDE has determined that owners of storm drain systems that implement the requirements of this permit will be controlling stormwater pollution to the maximum extent practicable. Therefore, satisfying the conditions of this permit will meet waste load allocations specified in Total Maximum Daily Loads (TMDL) developed for impaired water bodies.

However, we are aware that the next permit term will have greater TMDL involvement with waste load allocation requirements. To this end, SHA is working to develop a TMDL implementation strategy for our agency that will encompass many facets of our organization on many levels. Some of these aspects are discussed below.

Utilizing GIS to Make Decisions and Demonstrate Compliance

Now that SHA has completed both the source identification process and the impervious surface accounting requirement for the nine phase I counties, we have spatial data for our impervious surfaces and our stormwater BMPs. These two components can be used for determining our pollutant loadings (impervious surfaces combined with roadway classification) and our benefits (stormwater BMP type, condition and treatment area). See Appendix G for maps of all nine counties for nutrients and sediment impairments overlaid with SHA impervious surfaces and stormwater BMPs. (Note that the impairment and Tier II data was acquired from the MDE Science Services Administration and the accuracy was not verified by SHA.) Figures 1-11 and 1-12 are examples of the mapping for Carroll County.

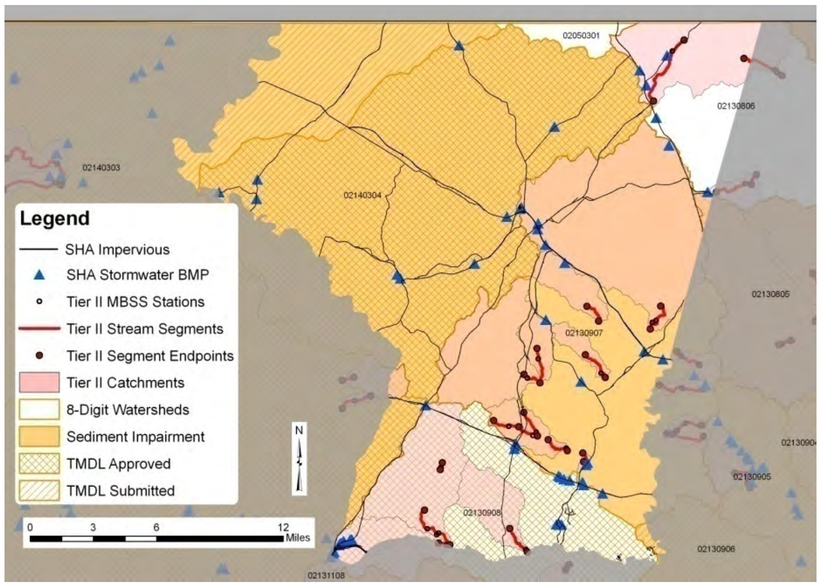


Figure1-11 Carroll County GIS – Sediment

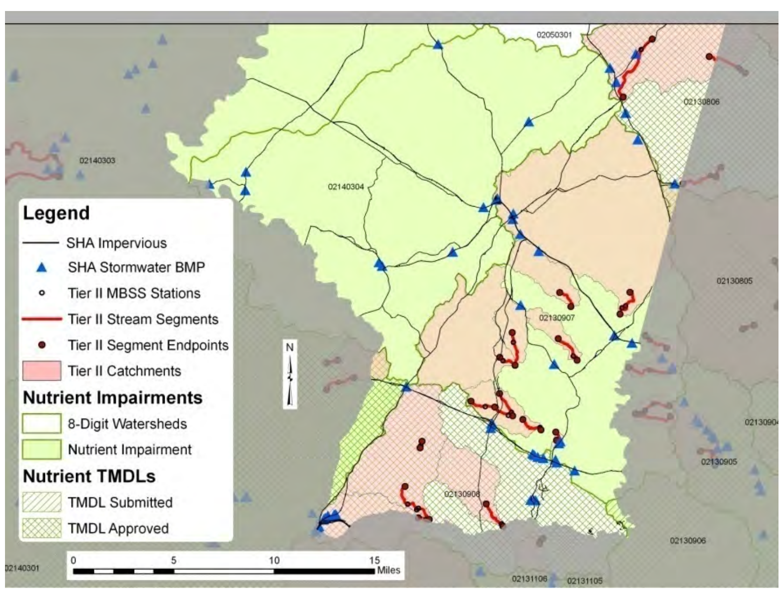


Figure1-12 Carroll County GIS -- Nutrients

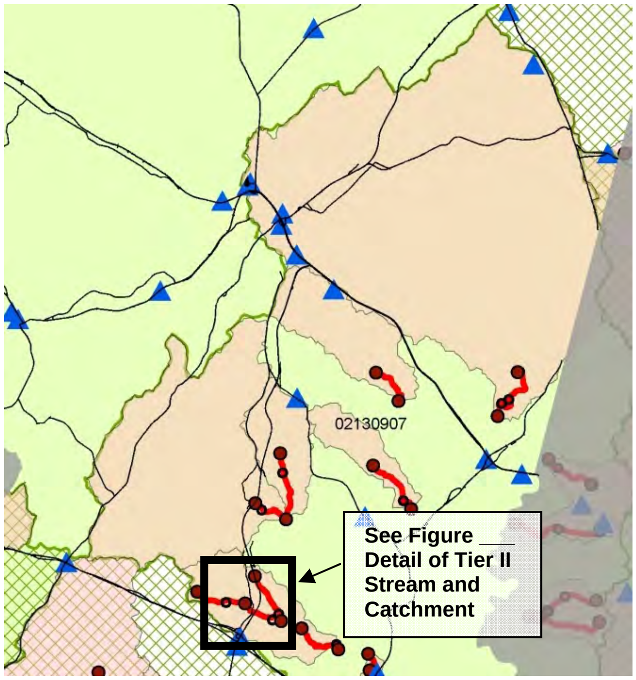


Figure 1-13 Tier II Streams (red) with Nutrient Impairments (green) in Carroll County. SHA impervious surfaces are black lines while SHA SWM BMPs are blue triangles.

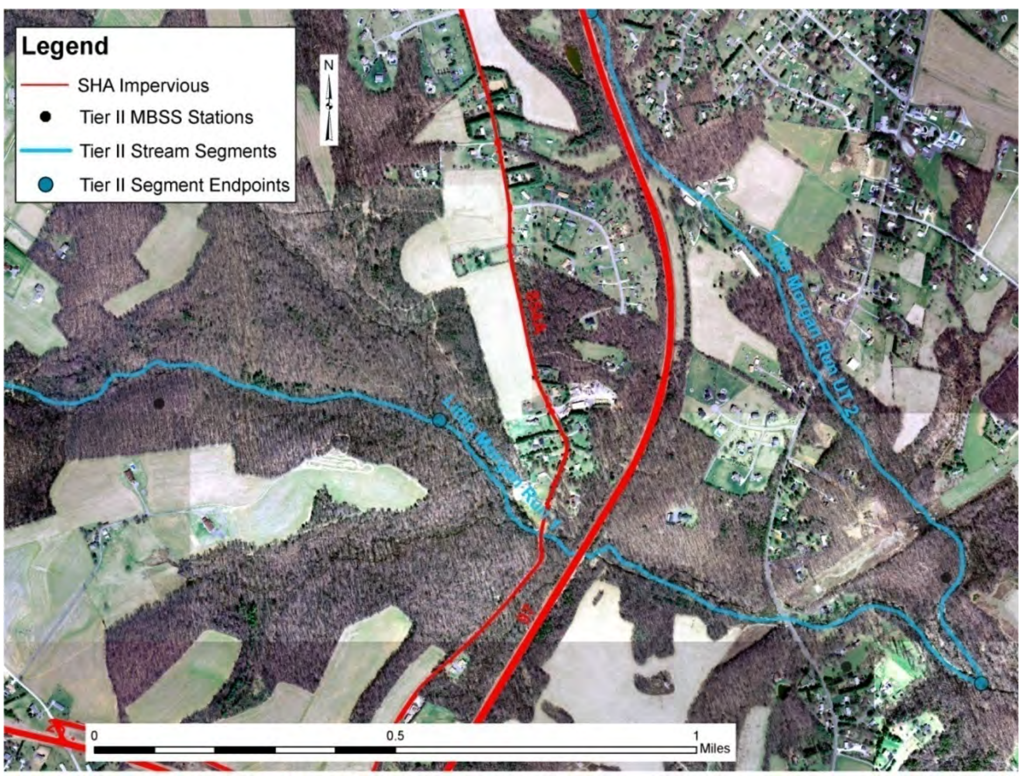


Figure 1-14 Detail of Little Morgan Run – Tier II Stream Segments

This information can now be used in developing strategies and methodologies for several key initiatives including:

- Develop methodologies to demonstrate compliance or non-compliance with TMDLs by modeling SHA pollutant loadings at the 8-digit watershed level;
- Strategize Consolidated Transportation Plan (CTP) updates by moving away from sensitive watersheds with development or employing appropriate BMPs to mitigate the affect of development;
- Strategize compliance with the anti-degradation policy for Tier II streams and catchments;
- Develop a toolbox of BMPs that are effective for particular pollutant removals that includes structural stormwater BMPs, non-structural stormwater BMPs, good housekeeping and educational initiatives targeted to watershed-level stakeholders. Some toolbox items may include:
    - Structural or non-structural stormwater management facilities,
    - Outfall stabilization,
    - Stream restoration,
    - Stream buffer plantings,
    - Street sweeping,
    - Inlet and pipe cleaning,
    - Impervious surface reduction or pervious pavement,
    - Mowing reduction and native meadows to reduce nutrient application, and
    - Sponsor-a-highway partnerships for litter removal.

For example, in Figure 1-13, the light red areas are Tier II stream catchments. These areas lie within a bigger 8-digit watershed that has impairments for nutrients. SHA might target the catchment areas within the 8-digit watershed 02130907, Liberty Reservoir, by locating a number of stormwater BMP measures along roadway corridors within that watershed. Figure 1-14 shows detail of an area at Little Morgan Run (a Tier II Stream) at the MD 97 crossing.

This approach would entail cooperation among many entities within SHA, within the communities and within the local government jurisdictions. We are at the beginning of the process to tie all our internal stakeholders together in developing the process for maximizing watershed restoration credits, meeting TMDLs and addressing the anti-degradation policy.

Patuxent River Watershed Restoration Project

SHA is currently working on identifying watershed restoration projects within the Patuxent River watershed and is developing an approach utilizing watershed impairment, TMDL and Tier II stream information to identify potential sites for ESD micro-scale, ESD non-structural, structural or good housekeeping BMPs.

Once sites are identified, a report documenting our process will be developed; projects will be designed, advertised and constructed; the resulting BMPs will be documented in our GIS and the projects will be added to our restoration credit database.

See Figure 1-15 for a graphic of the Patuxent River Area that identifies the Phase I counties affected. This graphic also shows the SHA impervious surfaces and stormwater management structural BMPs in that watershed.

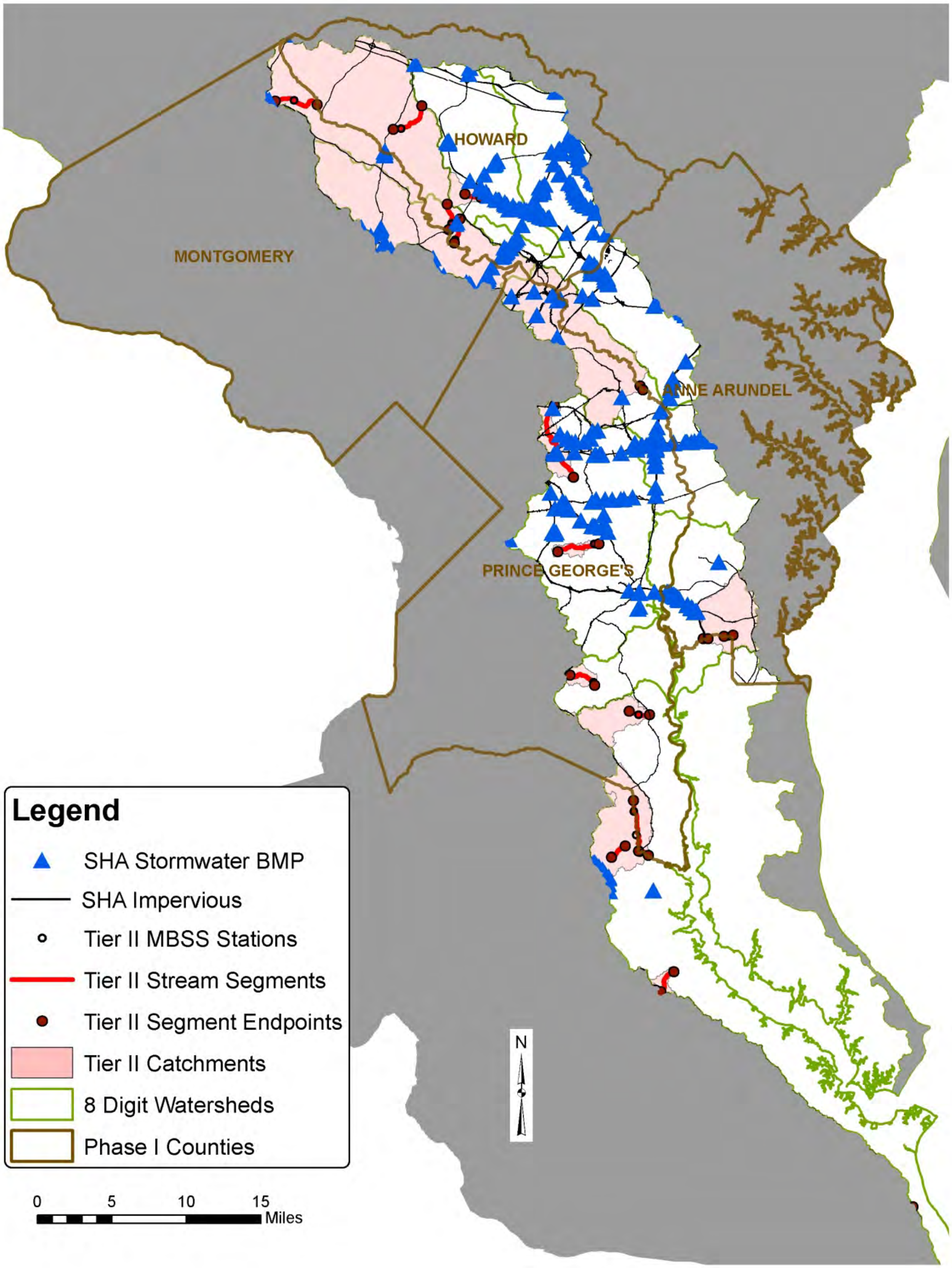


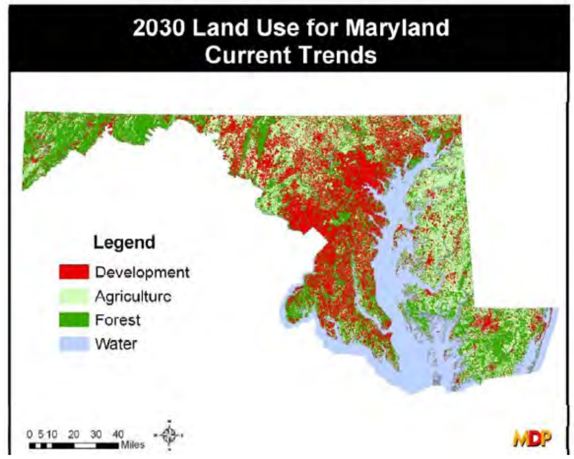
Figure 1-15 Patuxent River Watershed with NPDES Phase I Counties

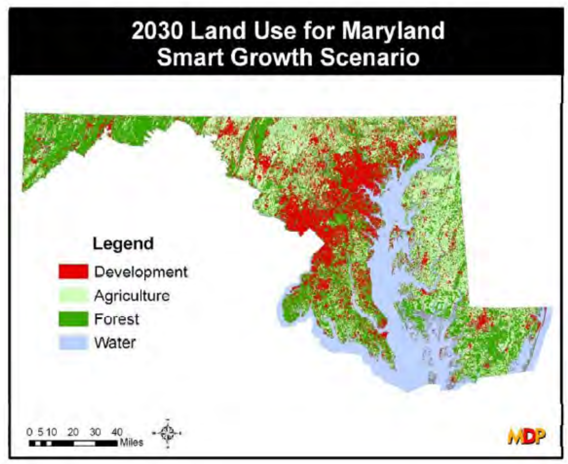
CTP Development and Growth Trends

Future trends in development are important to understand in order to target future road improvements to those areas where growth is desired and away from those where growth is not. The base data discussed above will be critical to managing this growth by carefully considering the placement of roads in more urbanized areas as the environmental resources in those areas will be highly stressed. This will create certain efficiencies in impervious area accounting and treatment. It will also preserve important environmental features such as wetlands, habitat, and green infrastructure. Development of the Consolidated Transportation Plan (CTP) can be predicated upon these trends.

Critical Thinking and Imperviousness

SHA will address critical thinking concerning placement of impervious surfaces. Planning road improvements by strategically implementing stormwater management will become paramount. Also of importance will be the recognition that functional classifications of roadways and the associated vehicle usage numbers are important in assessing pollutant loadings. Areas of higher usage will produce more pollutant loads than areas of less use. Methods to reduce pollutant loadings can be concentrated in areas or highest concern.



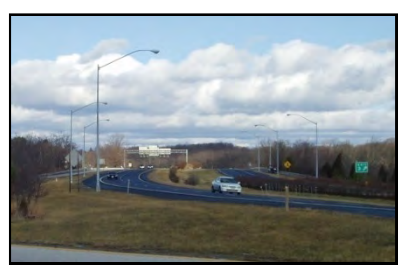


Different Scenarios for 2030 Growth Patterns in Maryland

Figure 1-16 illustrates the categories of urban and rural classifications (lane miles for each SHA district broken out by functional classification). While most of the Phase I counties are characterized by a majority of urban classified roadways, Charles, Carroll and Frederick counties are characterized by mostly rural roadways.

Park N Ride

Urban Interstate



Rural Interstate

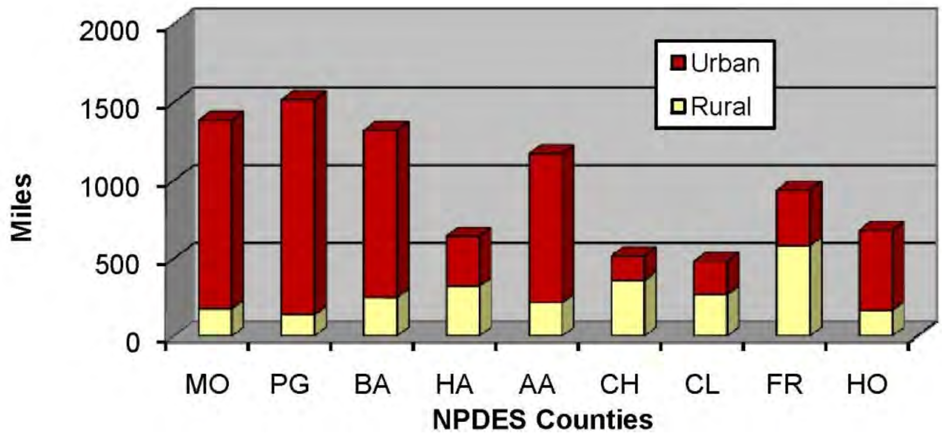


Figure 1-16 SHA Roadway Functional Classifications by NPDES County
(2007 Lane Miles)

Rural Roadway Classifications:	**Urban Roadway Classifications:**
Interstate	Interstate
Other Principal Arterial	Other Freeways & Expressways
Minor Arterial	Other Principal Arterial
Major Collector	Minor Arterial
Minor Collector	Collector
Local	Local

PART TWO

NPDES MS4 Phase I Permit Re-Application

The Maryland State Highway Administration (SHA) is re-applying for authorization under the NPDES municipal separate storm sewer system permit. The current permit expires October 21, 2010. There are four areas that the permit requires we address at a minimum in this re-application. They are:

1. *SHA NPDES Stormwater Program Goals;*
2. *Program Summaries for the Permit Term regarding:*
   a. *Illicit Discharge Detection and Elimination (IDDE) results;*
   b. *Watershed Restoration status including SHA totals for impervious acres, impervious acres controlled by stormwater management, and the current status of watershed restoration projects and acres managed;*
   c. *Pollutant load reductions as a result of this permit;*
   d. *Other relevant data and information for describing SHA programs;*
3. *Program Operation and Capital improvements costs for the permit term;*
4. *Descriptions of any proposed permit condition changes based on analyses of the successes and failures of the SHA efforts to comply with conditions of this permit.*

SHA NPDES Program Goals

The several programs within the NPDES Permit Program have individual goals. They include:

- Adhere to NPDES MS4 Permit Conditions to the Maximum Extent Practicable;
- Maximize Performance in ESC for SHA Projects;
- Maintain the SHA Stormwater Facilities to Operate as Designed and to Strategically Enhance their Functions to Meet Today's Stormwater Standards.

Illicit Discharge Detection and Elimination (IDDE) Results

Our current program has proven effective at discovering illicit discharges but not consistently effective in ensuring they are disconnected. We have developed a procedure to increase the effectiveness of elimination over the next year. The results of our IDDE program are listed in Table 2.1.

Table 2-1 Illicit Discharge Screenings to Date

County	Outfalls Screened	Outfalls w/ Flow Observed	Illicit Discharge Reports	Delivered to Jurisdiction	Date Delivered
Frederick	46	46	16	County NPDES Coordinator	9/11/2007
Harford	53	16	1	No Records	
Howard	209	172	2	County NPDES Coordinator	01/10/2008
Montgomery	217	26	3	County NPDES	01/10/2008

Table 2-1 Illicit Discharge Screenings to Date

County	Outfalls Screened	Outfalls w/ Flow Observed	Illicit Discharge Reports	Delivered to Jurisdiction	Date Delivered
				Coordinator	
Charles	85	27	0		
Carroll	104	84	7	County NPDES Coordinator	8/14/2008
Anne Arundel[1]	101	10	0		
Prince George's[1]	163	22	0		
Baltimore[1]	77	16	1	County NPDES Coordinator	10/09/2009
Howard[1]	9	3	0		
Totals	**1059**	**422**	**30**		

Notes: 1. GIS development is currently under way but not completed.

Watershed Restoration Status

SHA has completed the impervious accounting and has roughly 24,758 acres of impervious surfaces within the nine phase I counties. We have quantified the treatment provided by structural stormwater BMPs to be 2,456 acres which is roughly 9.9 percent of the impervious surfaces treated by stormwater management. In keeping with the spirit of the 2007 Stormwater Law and Environmental Site Design (ESD), we are currently researching existing non-structural treatment and will add this to our accounting as we do annual updates to the treatment.

There are currently 105 watershed restoration projects in varying stages of completion. Project types range from stormwater BMP retrofit upgrades to current regulatory standards, stream restoration and stream stabilization. We are working to develop new BMPs that treat existing untreated impervious surfaces as well as add existing restoration projects to the list such as outfall stabilization.

Of the 105 projects, 62 are completed that treat 385 acres of impervious. The 105 projects will treat 671 acres.

Pollutant Load Reductions

Efforts to update the Chesapeake Bay Model as well as TMDL establishment have been in progress by regulating entities during this permit term. Hence, SHA has not computed anticipated pollutant load reductions for our roadways within these nine counties. These computed reductions are based upon many assumptions and models that provide rough estimations. We think that investing the resources to complete this task separate from the current modeling efforts already being conducted by MDE in developing TMDLs and in working with the Chesapeake Bay model will be counter productive. We are instead, working to provide our data to the Science Services Administration and coordinate with them on the assumptions they make in modeling the SHA contribution to pollutant loads in both these modeling arenas. These efforts will continue over the coming years.

For future TMDL compliance, SHA is working to put together a model that will allow us to demonstrate our involvement in the waste load allocations in order that we can demonstrate compliance with the TMDL or ascertain what actions need to be taken by SHA in order to bring our facilities into compliance. This modeling will be on an 8-digit watershed level.

Program Operation and Capital Improvement Costs

The SHA NPDES program has spent over 28.5 Million over the course of the current permit. We have another year to go and anticipate spending another 5 million, bringing the total up to over 33.5 Million.

Proposed Permit Condition Changes

Maintaining compliance with the NPDES MS4 permits is a high priority with SHA. We have found success in implementing many of the permit conditions such as the training and educational efforts. The Stormwater Management Facilities Program and the Erosion and Sediment Control Program are both offering many opportunities to improve the impact our activities have on the surrounding waterways.

The conditions associated with this permit are many and complicated and we think that the simpler the requirement to report on and account for compliance, the better. It would be helpful if MDE could provide more guidance on BMP pollutant removal efficiencies or act as a clearinghouse for reports and information developed by the NPDES jurisdictions. This could be in the form of a web page where all the information is made available to the jurisdictions for download. For example, reports other jurisdictions have performed in determining load reductions for various BMPs could be made available to everyone in this way.

We have worked to maintain good relationships with MDE and the local jurisdictions. However, given limited staffing resources and the complexity of the permit requirements and implementation within local jurisdictions, we find that developing on-going interactions is difficult to achieve. Instead, an annual information exchange among the MS4 permitees may be beneficial to many. It can provide a platform to have consistency in information sharing or goal setting.

We also foresee that the upcoming implementation of ESD will increase the demand on our ability to execute the NPDES permit compliance as it is written today. The number of stormwater facilities or types of ESD that are non-structural (such as conservation credit or disconnection of non-rooftop surfaces) will require careful examination of how to implement tracking and maintenance methods of these myriad facilities. SHA requests that we be active participants in discussions concerning managing these assets before permit conditions are imposed that could potentially overload our stormwater program. We are willing to provide necessary information to MDE if desired to assist in this process.

Related to the above concern is the current requirement for stormwater BMP inspection be performed every 3 years with any necessary remediation completed a year after that. We request that a 5 or 6 year inspection and maintenance cycle be considered.

Also, the impervious surface accounting update requirement that was mentioned in the comments received in September asks for annual updates to the impervious accounting. We ask that it be understood that the layers will be updated as newer ortho-photography becomes available but that the treatment can be updated annually.

We find that the pollutant load reduction computations that are to be calculated for our entire permit area for the entire permit term are burdensome. This modeling may be unnecessary when so many other modeling efforts are looking at the same areas. We request that this requirement be lifted and that coordination among the various jurisdictions and MDE be fostered by the MDE to facilitate better implementation of the tributary action plans, TMDL compliance and Chesapeake Bay restoration.

Lastly, the impending application of required percentages of impervious surfaces treated as 'restoration credit' will be a financial strain on our program. Our estimate to meet a 10 percent requirement is in the neighborhood of a Billion dollars. That sum spread over a five year period is not achievable by any means.

We ask that you consider our input and we thank you for your continued support and cooperation with us. SHA looks forward to many years of working toward improved water quality and ultimately a restored Chesapeake Bay.

PART THREE

Stormwater Management Facilities Program

3.1 Introduction

This section of the report summarizes the Maryland SHA Stormwater Management (SWM) Facilities Program activities between October 2008 and October 2009.

Based on the latest estimates SHA owns about 2,023 stormwater management (SWM) facilities statewide that were constructed since the mid 1970's. Since 1999, SHA has managed a comprehensive program to locate, inspect, evaluate, maintain and remediate BMPs to sustain their functionality, improve water quality, and protect sensitive water resources.

The program's primary goal is to maintain SHA's stormwater facilities to operate as designed and to strategically enhance their functions to meet today's stormwater standards. The SWM Facilities Program consists of four major components:

- Identification, inspection and database development to manage SHA assets,
- Maintenance and Remediation of BMPs,
- Visual and environmental quality enhancements, upgrades and retrofits,
- Monitoring, research and technology tools development.

The program focuses on the remediation and enhancement of BMPs. This effort requires continuous improvement of the BMP inspection procedures, data management system, tools to track the performance and remediation actions. SHA has developed a prioritization system for remedial activities, and to develop new technologies for repairing or retrofitting BMPs including visual and functional enhancement projects. A part of the SWM Facilities Program is research on performance and efficiency of commonly used BMPs.

3.2 Inventory and Inspection

The following section summarizes the inspection system and inventory results to provide a status of SHA-owned SWM facilities.

3.2.1 Inspection Protocol

The key to an efficient maintenance program is a detailed and consistent inspection assessment. Therefore, SHA has updated the BMP inspection manual that became Chapter 3 of the NPDES Standard Procedures Manual.

Performance Rating

The initial assessment of a SWM facility is a field inspection where individual parameters are *scored* (on a scale 1 to 5) then used to establish an overall BMP performance rating:

A **No Issues** – BMP functioning as designed with no problem conditions identified. There are no signs of impending deterioration.

B **Minor Problems** are observed, however, BMP is functioning as designed.

C **Moderate Problems** are observed, however BMP is functioning as designed, but some parameters indicate the performance and functionality are compromised.

D **Major Problems** are observed, and the facility is not functioning as designed. Several issues may exist that have compromised the BMP performance or indicate failure

E **Severe Problems** exist, and the facility is not functioning as designed with several critical parameters having problem conditions. BMP facility shows signs of deterioration and/or failure. Remedial action should be performed immediately.

The inspection protocol is summarized in the recently updated guidance document "*Best Management Practice Field Inspection & Collection Procedures*", dated January 2008. The manual documents the methodologies used in the field for identifying, locating, and inspecting SWM facilities statewide. SHA has expanded the protocol to include criteria for visual quality as well as inspection for potential water quality and visual enhancements.

SHA Remediation Rating

SHA performs qualitative evaluation for maintenance and remediation by assigning the remedial rating. This is based on the overall initial inspection rating, performance, functionality, integrity and visual appearance; and also scope and complexity of the potential remedial work:

I **No Response Required** – schedule for multi-year inspection.

II **Minor Maintenance** – perform as necessary to sustain BMP performance. Upon remedial action and re-inspection, can be candidate for multi-year inspection.

III **Major Maintenance or Repair** – is needed to return the site to original functionality within the existing footprint of the facility. Structural defects require repair and/or restoration.

IV **Retrofit Design** – is required on-site or at another location, since BMP cannot be returned to its original functionality within its existing footprint.

V **Immediate Response** – is mandatory to address any public safety hazards regardless of the functionality of the BMP.

VI **Abandonment** – of the BMP when the facility is not maintainable and will not provide sufficient benefits if retrofitted due to the lack of access for construction and maintenance, limited space or minimum impervious area treated.

3.2.2 Inventory

BMP Inventory is being performed countywide on SHA's roadways in Maryland jurisdictions with Phase I and II MS4 permits, and on a district-level. Table 3-1 summarizes the total number of BMPs identified in each County and SHA District. Figure 3-1 provides a statewide status of the SWM Program in terms of identification, inspection and remediation as of October 2009.

Table 3-1 Current Statewide SWM Facilities

District	County	No. BMPs	Totals
1	Dorchester	24	150
	Somerset	13	
	Wicomico	46	
	Worchester	67	
2	Caroline	4	139
	Cecil	11	
	Kent	6	
	Queen Anne's	102	
	Talbot	16	
3	Montgomery	266	456
	Prince George's	190	
4	Baltimore	167	277
	Harford	110	
5	Anne Arundel	422	590
	Calvert	41	
	Charles	100	
	St. Mary's	27	
6	Allegany	40	68
	Garrett	12	
	Washington	16	
7	Carroll	35	343
	Frederick	62	
	Howard	246	
State			**2,023**

BMP inventories are being constantly updated as remediation and retrofit projects are completed. In some instances, SWM may be replaced, consolidated, retrofitted, constructed or re-constructed by a private developer to serve as a Joint Use facility. In order to track pending changes in BMP inventory, SHA keeps improving the internal process and database management tools. As the inventory spans statewide, major efforts of inspection and maintenance are strategically expedited in NPDES counties.

3.2.3 Field Inspection

The BMP inventories in counties listed under Phase I and II MS4 jurisdictions in the SHA NPDES Permit are being performed as part of the source identification. In addition, SHA is inventorying and inspecting BMP in non-MS4 counties. SHA previously completed the inspections in Montgomery, Howard, Anne Arundel, Prince George's, Kent, Queen Anne's, Baltimore, Harford, Garrett, Allegany, Washington, Carroll, Charles, and Frederick Counties.

Inventory and inspections have been completed in Calvert, St. Mary's, Cecil, Caroline, and Talbot Counties. Re-inspections are currently being preformed in Anne Arundel, Baltimore, Howard and Prince Georges Counties. The remedial rating for each inspected county is summarized in the Table 3-2.

Table 3-2 SWM Facilities Remedial Ratings Summary by County

Type of SWM Facility	Number Inspected	Rating			
		I	II	III	IV
Allegany County					
Detention	13	6	0	7	0
Extended Detention	13	10	0	0	3
Retention	4	2	2	0	0
Infiltration Basin	0	0	0	0	0
Infiltration Trench	5	5	0	0	0
Shallow Marsh	0	0	0	0	0
Other	5	5	0	0	0
Totals	**40**	**28**	**2**	**7**	**3**
Anne Arundel County					
Detention	45	40	0	3	2
Extended Detention	6	6	0	0	0
Retention	45	41	2	1	1
Infiltration Basin	56	35	2	2	17
Infiltration Trench	264	171	42	16	35
Shallow Marsh	2	2	0	0	0
Other	4	3	1	0	0
Totals	**422**	**298**	**47**	**22**	**55**
Baltimore County					
Detention	28	22	4	2	0

Table 3-2 SWM Facilities Remedial Ratings Summary by County

Type of SWM Facility	Number Inspected	Rating			
		I	II	III	IV
Extended Detention	4	3	0	1	0
Retention	17	15	0	2	0
Infiltration Basin	35	25	0	3	7
Infiltration Trench	70	42	7	7	14
Shallow Marsh	8	6	1	1	0
Other	5	4	1	0	0
Totals	**167**	**77**	**9**	**11**	**21**
Caroline County					
Detention	1	0	1	0	0
Extended Detention	0	0	0	0	0
Retention	2	0	1	1	0
Infiltration Basin	0	0	0	0	0
Infiltration Trench	0	0	0	0	0
Shallow Marsh	0	0	0	0	0
Other	1	0	0	1	0
Totals	**4**	**0**	**2**	**2**	**0**
Carroll County					
Detention	0	0	0	0	0
Extended Detention	0	0	0	0	0
Retention	3	2	1	0	0
Infiltration Basin	2	2	0	0	0
Infiltration Trench	19	18	1	0	0
Shallow Marsh	0	0	0	0	0
Other	11	7	3	1	0
Totals	**35**	**29**	**5**	**1**	**0**
Cecil County					
Detention	0	0	0	0	0
Extended Detention	0	0	0	0	0
Retention	5	1	3	1	0
Infiltration Basin	0	0	0	0	0
Infiltration Trench	2	0	2	0	0
Shallow Marsh	0	0	0	0	0
Other	4	0	3	1	0
Totals	**11**	**1**	**8**	**2**	**0**

Table 3-2 SWM Facilities Remedial Ratings Summary by County

Type of SWM Facility	Number Inspected	Rating			
		I	II	III	IV
Charles County					
Detention	5	2	3	0	0
Extended Detention	1	1	0	0	0
Retention	14	3	11	0	0
Infiltration Basin	7	2	1	3	1
Infiltration Trench	43	6	8	21	8
Shallow Marsh	0	0	0	0	0
Other	30	22	8	0	0
Totals	**100**	**36**	**31**	**24**	**9**
Frederick County					
Detention	14	14	0	0	0
Extended Detention	0	0	0	0	0
Retention	15	15	0	0	0
Infiltration Basin	2	2	0	0	0
Infiltration Trench	12	11	1	0	0
Shallow Marsh	1	1	0	0	0
Other	18	16	2	0	0
Totals	**62**	**59**	**3**	**0**	**0**
Garrett County					
Detention	2	1	1	0	0
Extended Detention	2	2	0	0	0
Retention	2	1	1	0	0
Infiltration Basin	0	0	0	0	0
Infiltration Trench	4	4	0	0	0
Shallow Marsh	0	0	0	0	0
Other	2	2	0	0	0
Totals	**12**	**10**	**2**	**0**	**0**
Harford County					
Detention	15	11	3	1	0
Extended Detention	6	4	1	1	0
Retention	9	8	1	0	0
Infiltration Basin	18	15	3	0	0
Infiltration Trench	59	30	11	1	17
Shallow Marsh	3	3	0	0	0

Table 3-2 SWM Facilities Remedial Ratings Summary by County

Type of SWM Facility	Number Inspected	Rating			
		I	II	III	IV
Other	0	0	0	0	0
Totals	**110**	**71**	**19**	**3**	**17**
Howard County					
Detention	11	11	0	0	0
Extended Detention	27	27	0	0	0
Retention	27	24	1	2	0
Infiltration Basin	18	9	0	1	8
Infiltration Trench	126	113	0	0	13
Shallow Marsh	16	16	0	0	0
Other	21	18	1	2	0
Totals	**181**	**156**	**1**	**3**	**21**
Kent County					
Detention	0	0	0	0	0
Extended Detention	4	3	1	0	0
Retention	1	1	0	0	0
Infiltration Basin	0	0	0	0	0
Infiltration Trench	0	0	0	0	0
Shallow Marsh	0	0	0	0	0
Other	1	1	0	0	0
Totals	**6**	**5**	**1**	**0**	**0**
Montgomery County					
Detention	29	26	1	0	2
Extended Detention	27	25	0	2	0
Retention	43	35	3	3	2
Infiltration Basin	18	14	1	1	2
Infiltration Trench	120	104	7	5	4
Shallow Marsh	6	6	0	0	0
Other	23	21	2	0	0
Totals	**266**	**231**	**14**	**11**	**10**
Prince George's County					
Detention	12	11	0	0	1
Extended Detention	4	2	1	0	1
Retention	40	34	5	0	1
Infiltration Basin	15	12	0	3	0
Infiltration Trench	89	46	18	15	10

Table 3-2 SWM Facilities Remedial Ratings Summary by County

Type of SWM Facility	Number Inspected	Rating			
		I	II	III	IV
Shallow Marsh	23	21	1	0	1
Other	7	6	0	1	0
Totals	**190**	**132**	**25**	**19**	**14**
Queen Anne's County					
Detention	2	2	0	0	0
Extended Detention	0	0	0	0	0
Retention	16	12	0	3	1
Infiltration Basin	1	1	0	0	0
Infiltration Trench	8	6	0	1	1
Shallow Marsh	11	9	0	2	0
Other	64	1	63	0	0
Totals	**102**	**31**	**63**	**6**	**2**
Talbot County					
Detention	0	0	0	0	0
Extended Detention	0	0	0	0	0
Retention	0	0	0	0	0
Infiltration Basin	2	1	0	0	1
Infiltration Trench	1	1	0	0	0
Shallow Marsh	0	0	0	0	0
Other	3	2	1	0	0
Totals	**6**	**4**	**1**	**0**	**1**
Washington County					
Detention	8	7	1	0	0
Extended Detention	0	0	0	0	0
Retention	2	2	0	0	0
Infiltration Basin	2	1	1	0	0
Infiltration Trench	2	2	0	0	0
Shallow Marsh	0	0	0	0	0
Other	2	2	0	0	0
Totals	**16**	**14**	**2**	**0**	**0**

STORMWATER MANAGEMENT FACILITIES
INSPECTION AND REMEDIATION PROGRAM

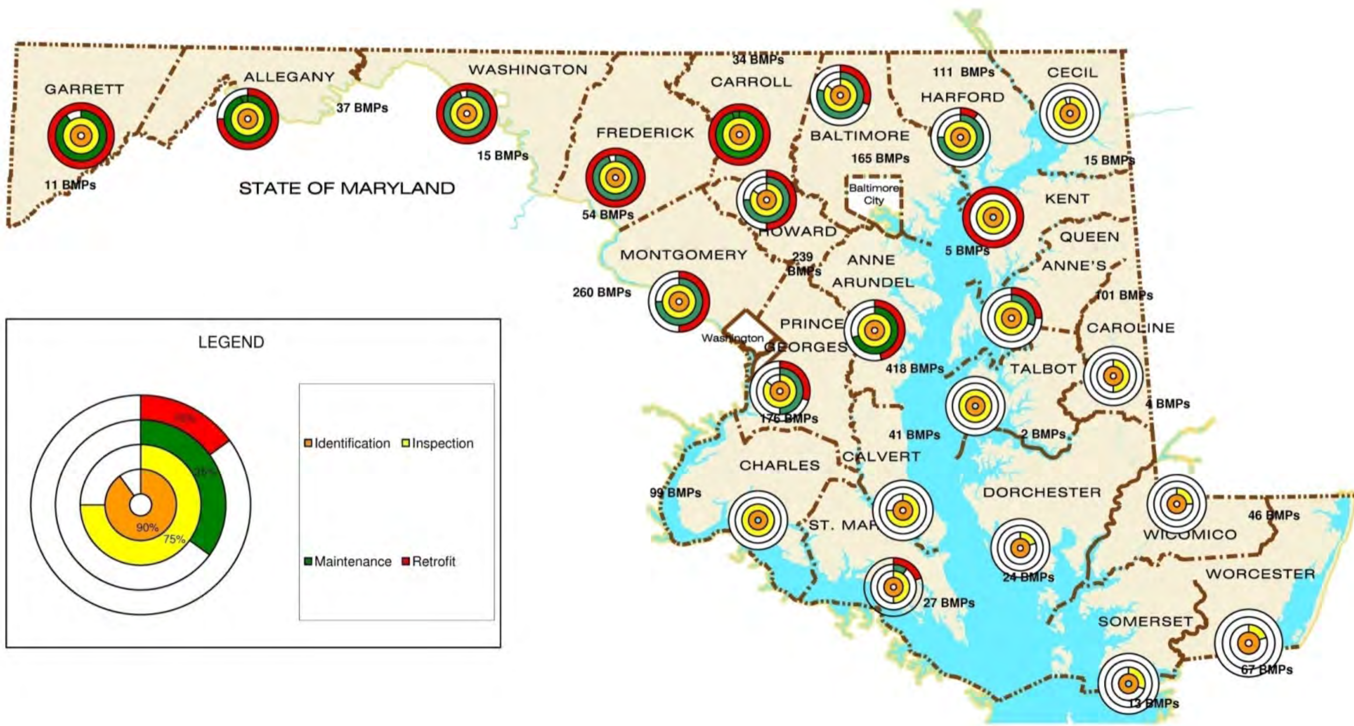


Figure 3-1 SWM Facilities Inspection and Remediation Program

3.3 Maintenance & Remediation

This section summarizes the status of SHA maintenance and remedial responses to deficiencies identified through the inspections of SWM facilities. The program's primary goal is to keep SHA stormwater facilities operating as designed and to strategically enhance their functions. The responses are separated between routine maintenance major maintenance and retrofit projects. Figure 3-1 shows the status of the remediation responses by either maintenance or retrofit/enhancement design.

3.3.1 Routine Maintenance

Routine maintenance or preventive maintenance is generally considered a repair activity that addresses minor issues. The objective is to maintain performance of a BMP and/or to avoid deterioration of specific BMP elements. SWM facilities that require routine maintenance are assigned "II" rating by SHA.

SHA has currently completed most of routine maintenance in many of the inspected counties using several HHD Open Ended Maintenance contracts that as well as District Maintenance Shops Forces in District 7 , specifically in Carroll and Howard Counties. The maintenance crews perform both routine and major/remedial maintenance.

Upon completion the statewide inventory database and one cycle of remedial maintenance in each county, the SWM routine and preventive maintenance tasks may be managed by individual SHA District Maintenance Shops within their jurisdiction as part of the roadside maintenance. SHA is currently developing maintenance guidelines and procedures to strategically schedule statewide SWM maintenance.

Table 3-3 lists the number of facilities requiring routine maintenance based on the 2009 inventory datat and the total number that were maintained since the last report to this date. The Table 3-3 also summarizes the routine maintenance cost by county between October 2008 and October 2009.

In order to perform SWM facilities maintenance more effectively, SHA is implementing an innovative contracting approach by advertising SWM Facilities Design, Operate and Maintain Project (DBOM) for Charles County. The project was advertised in September 2008 and the notice to proceed will be given in August 2009 to the selected winning team composed of an engineering company partnering with a construction firm with SWM maintenance experience. During the next three years, the team is responsible for a countywide SWM remedial and routine maintenance performed twice a year, as well as BMP inspections, inventory database updates. Nine previously identified SWM retrofits will designed and constructed by the end of this 3 year contract.

Table 3-3 Minor Maintenance Summary

County	District	BMPs for Maintenance	BMPs Maintained10/2008 to 10/2009	Cost
Anne Arundel	5	58	14	$120,879
Carroll	7	11	6	$16,596
Total		**69**	**20**	**$137,475**

3.3.2 Major Maintenance

SHA performs major maintenance tasks that address significant deficiencies at BMPs through the time & material open ended contract lead by Highway Hydraulics Division. The intent is to restore performance of a BMP and/or to avoid failure of specific elements. SWM facilities that require major or remedial maintenance are assigned a "III" rating by SHA. Figure 3-2 shows an example of SWM Facility requiring major maintenance in terms of excavating of accumulated sediments in infiltration trench and replacing the media to restore its functionality.

Figure 3-2 BMP 020186 – Removal of Sediment from Infiltration Trench

SHA continues performing detailed field assessments for BMPs identified for major maintenance. A workorder and a summary report is prepared for each BMP that provides sketches using as-built plans, photographs, cost estimate, repair recommendations, specifications and MOT. Figures 3-3 and Figure 3-4 show very typical remediation activity – SWM pond vegetative management, slope stabilization and inflow channel stabilization in Howard County.

Major maintenance is underway in all inspected counties but the focus in the past year has been on Anne Arundel, Baltimore, Howard and Carroll Counties. Table 3-4 lists the total number of facilities requiring major maintenance and the total number that were maintained with the associated cost between October 2008 and September 2009.

Figure 3-3Inflow Channel Stabilization (BMP130292) - during construction

Figure 3-4 Inflow Channel Stabilization (BMP13007) – After Construction

Table 3-4 BMP Major Maintenance Summary

County	District	BMPs for Maintenance	BMPs Maintained 10/2008 to 10/2009	Cost
Anne Arundel	5	80	2	$34,535
Baltimore	4	40	7	$64,756
Carroll	7	14	10	$18,587
Howard	7	32	14	$184,964
			Total	**302,842.00**

3.3.3 Infiltration Trench Remediation

SHA continues remedial actions for infiltration trenches since they represent almost half of SHA's current SWM facilities inventory. The infiltration trenches were originally designed to provide water quality treatment for the first ½ in runoff based on the older MDE design standards. Nearly half of inspected the trenches have been identified as failed or requiring remediation.

Field inspections indicate large number of infiltration trenches without an observation well. SHA continuously installs the missing or broken observation wells in order to identify and monitor the trench functionality. The failed infiltration trenches are grouped into individual retrofit projects by which the sites are being redesigned and replaced by more suitable and efficient BMPs. Those retrofit projects are listed in Table 3-5. However, many sites do not allow retrofit to another BMP type due to the topographic and other site restrictions. Those infiltration trenches are replaced in-kind by removal of the existing media and excavating of the accumulated sediment from the trench bottom. In the past year, most of the trenches that have been replaced are located along MD 43 in Baltimore County and along major highways throughout Anne Arundel County. This initiative is demonstrated in Figures 3-5 to 3-7.

Figure 3-5 Excavation of Infiltration Trench 020191

Figure 3-6 Infiltration Trench 020193 In-Kind Replacement

Figure 3-7 Infiltration Trench 210013 In-Kind Replacement

3.3.4 SWM Retrofits, Visual and Functional Enhancement Projects

MD SHA has actively continued design as well as construction phases of *SWM Functional Enhancement Projects* funded through State Fund for drainage improvements. When appropriate, SHA seeks partial funding match from the Transportation Equity Act for the 21st Century (TEA-21) Enhancement Funds. The projects have been initiated with the intention to improve the pollutant removal efficiency and bring the functional parameters up to the current standards required by the MDE 2000 *Maryland Stormwater Design Manual*, Volumes I and II and MDE *Guidelines for State and Federal Projects*, dated July 1, 2001. The new design criteria include groundwater recharge volume, and water quality volume. In addition to the functionality upgrades, the enhancement projects are intended to improve aesthetic value, provide refuge to local wildlife and increase the water quality benefits.

In previous reports, SHA provided a list of BMP retrofit/enhancement sites proposed in Anne Arundel and Prince Georges Counties. As the previously listed project have been constructed, new retrofit project are being initiated. The status of the current SWM Enhancement and Retrofit projects is summarized in Table 3-5. Figures 3-8 through 3-12 include recently completed enhancement projects in AA County.

Table 3-5: BMP Enhancement and SWM Retrofit Projects Summary

No	Project	County	No. of BMPs	Contract Number	Construction Cost Estimate	Status
1	Functional Enhancement of SWM Facilities – Phase 1	AA	4	AA3495174	$998,821	Construction completed in November 2008
2	Functional Enhancement of SWM Facilities - Phase 2	AA	7	AA5535174	$1,961,326	Construction completed in June 2009
3	MD 8- SWM Retrofit of BMO 170011 and 170012	QA	2	QA2835174	Preliminary $100,000	Under Design Preliminary Investigation
4	I-97 SWM Facilities Functional Upgrades	AA	12	AA5355174	$990,570	Bids Opened on September 17, 2009
5	Glen Burnie SHA Maint. Shop Bioretention Retrofit	AA	1	AA2735174	$300,000	Advertisement Date March 9, 2010
6	MD 235 - SWM Facility Retrofit	SM	1	SM356A21	PI Estimate $289,000	Under Design Semi- Final Review
7	MD 4 - Retrofit of Failed Infiltr. Basins & Trenches	AA	3	AA5515174	PI Estimate $400,000	Under Design Semi-Final Review
8	MD 355 – Retrofit of SWM Facility 150012	MO	1	MO410A21	$50,000	Will be constructed through Open End Contract
9	MD 32 and US 50 – Failed Infiltration Basins Retrofit	AA	10	AT560A21	Preliminary $1,800,000	Field Investigation, Concept design
10	I-270 SWM Retrofit of BMP 150059 and 150556	MO	2	AT650A21	Preliminary $200,000	Will be constructed through Open End Contract
	Total		**43**		**$7,089,717**	

Before the construction (11/2002) *After construction (07/2009*

Figure 3-8 Reconstruction of Failed Infiltration Basin into Sand Filter at MD 32 (BMP 020121)

Before the construction (11/2002

After construction (07/2009)

Figure 3-9 Functional Enhancement of Infiltration Basin at MD 100 into Shallow Wetland (BMP 020120)

During Construction (10/2008) *After construction (07/2009)*

Before the construction (11/2002) *During Construction (10/2008)* *After construction (07/2009)*

Figure 3-10 Reconstruction of Infiltration Basin at MD 32 into Pocket Pond (BMP020029)

Before construction (11/2002)

After construction (07/2008)

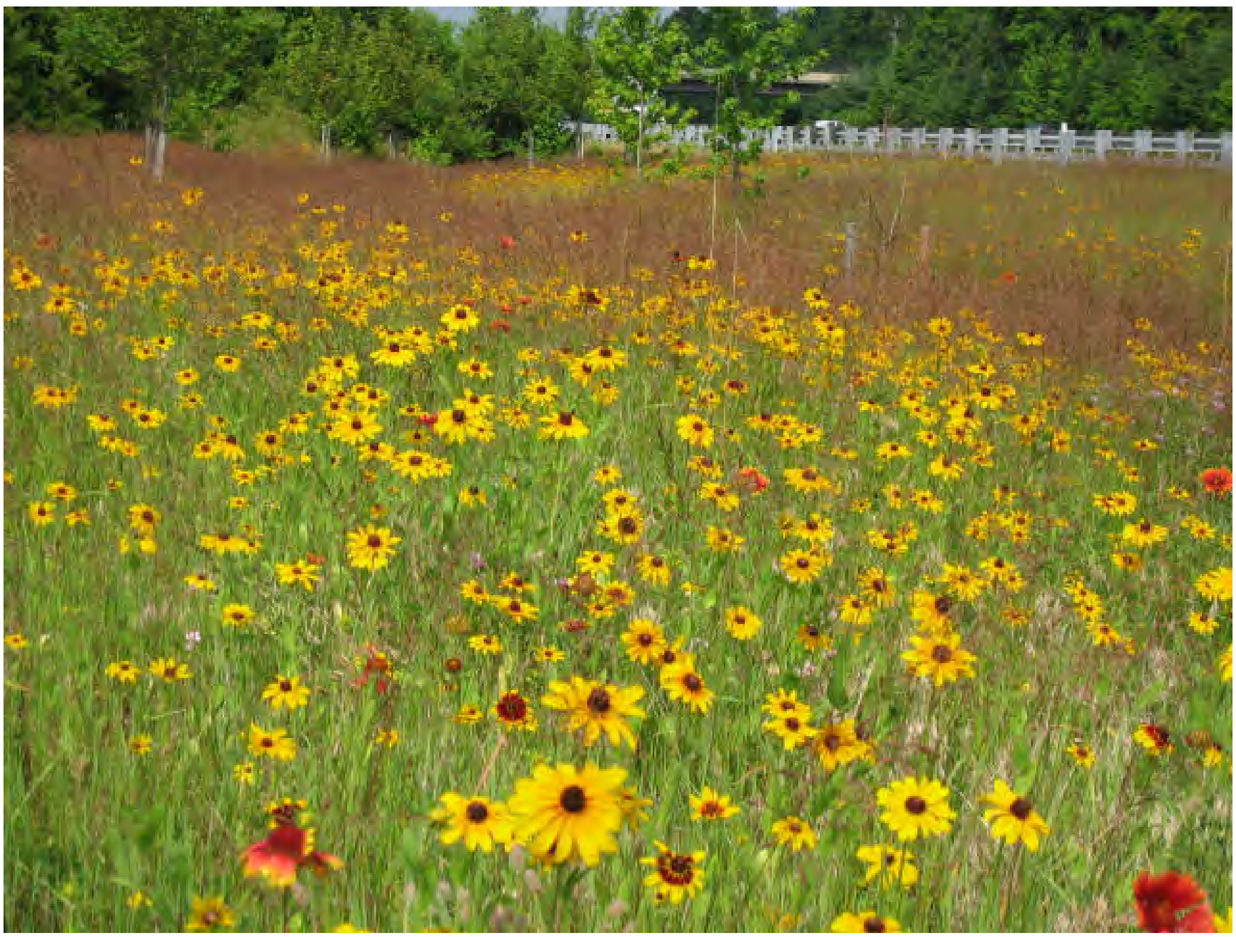


Figure 3-11 Reconstruction of failed Infiltration Basin at MD 100 into Sand Filter (BMP 020122)

Before construction (11/2002)

After Construction (07/2008)

After construction (07/2008)

Figure 3-12 Reconstruction of Failed Infiltration Basin at MD 100 into Micro-pool Extended Detention Pond (BMP 020111)

The design process of all SWM facilities included Visual Quality review as a part of the landscaping design to assure not only functional and sustainable BMP, but also aesthetically pleasing facility with successful establishment of the aquatic and upland plantings.

SHA continues the final design efforts with SWM Functional Upgrades project in Anne Arundel County – 12 failed infiltration trenches along I-97 and MD 100 listed in the previous report will be reconstructed. The project has been advertised in August 2009 and awaits Notice to Proceed in November 2009.

SHA continue develop retrofit design plans for number of SWM sites in Anne Arundel, St. Mary's and Queens Anne Counties to upgrade the existing BMP facilities. The new standard elements and criteria include channel protection volume, groundwater recharge volume, water quality volume, micropools, aquatic benches with wetland plantings, pre-treatment forebays, appropriate riser control structures to provide water quantity control and to minimize downstream adverse impacts, as well landscaping and visual enhancement to increase the aesthetic value of highly visible BMPs.

SWM retrofit project of failed biroretention at SHA Glen Burnie maintenance shop includes drainage improvements, outfalls stabilization as well as replacement of the existing BMP with more suitable BMP type for the site – sand filter. The project will be advertised in spring 2010 for construction Figure 3-13 shows the existing condition of the project site.

Figure 3-13 Failed Bioretention at SHA Glen Burnie Maintenance Shop

In summary, the proposed SWM retrofit and enhancement projects will contribute to improvement of water quality of highway runoff in the environmentally sensitive watersheds of Chesapeake Bay.

3.4 Other Topics

3.4.1 Data Management

To-date SHA has performed inventory of SWM drainage infrastructure in all NPDES counties and BMP inspections in all twenty-three counties with the intent to finalize statewide BMP inventory database by December 2009 SHA has preceded with the second cycle re-inspection in four counties. This effort involves continuous creation and updating of GIS data for source identification and database records for inspections and remediation activities.

SHA has finalized the structure of ESRI geodatabase and detailed schema that allows for the establishment and enforcement of topologic and/or network rules and unique data entry. The new database format resulted in improved data intelligence and integrity.

In order to stream line geodatabase updates procedure, SHA is developing automated Office Tool for quality assurance (QA) checks. In addition, a Field Tool has been developed for new field data collection, downloads and merging with main database. See Figure 1-14.

Figure 3-14 GPS and Field Tool Used for Efficient Data Entry During BMP Inspections

Along with the new database format, a new data viewer tool – NPDES Viewer- is being further enhanced. The functionality of this tool allows the user to view the spatial information as well as digital images associated with each BMP including as-built plans, photographs, inspection reports and other documents. BMP Viewer will be used to view data from various levels such as a highway corridor, MSHA district, County, or watershed.

The new component for BMP maintenance tracking called Remediation Tool is being added to the NPDES Viewer. This application will allow tracking maintenance activities, and associated cost as well retrofit project progress and current functionality of SHA owned SWM facilities.

The NPDES Viewer is being designed to provide functions that will help SHA staff to manage the overall SWM Program, as well as allow wide range of users to access the available BMP and drainage system data more efficiently in order to administer day-to-day activities.

The most recent tool incorporating BMP geodatabase that is used for quick data viewing, reporting and spatially displaying is a web application named iMap. (Screen captures are shown on Figure 3-15). The application can be found at http://www.mdimap.com/sha/

This tool was developed by SHA primarily for reporting the current status and progress of SHA Business Plan objectives to StateStat Committee. This tool was also used to present SHA SWM program at the Lt. Governor's meeting in July 2009.

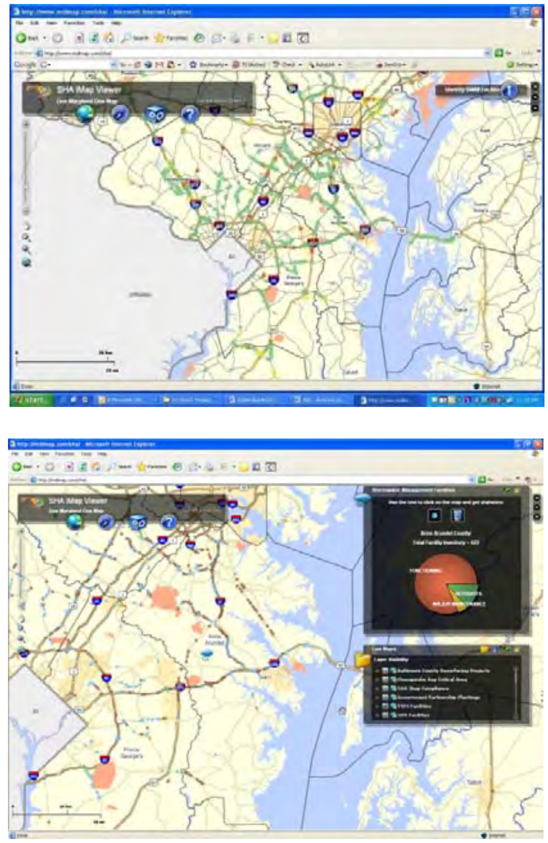


Figure 3-15 iMap Screen Captures

3.4.2 Standard Procedures

In order to maintain consistency and compatibility of the data collected during source identification and BMP inspections, SHA continues conducting NPDES Standard Procedures Workshop for outfall inspections, BMP inspections and illicit discharge screening. (Figure 3-16)

Approximately 25 consultants and SHA engineers completed the 2 day training in September 2009. Part of the workshop was also an overview of procedures summarized in Chapter 7 of NPDES Standard Procedures for SWM maintenance work order development.

Figure 3-15 SWM Inspection Workshop (September 2009)

3.5 Summary

SHA continues improving protocols and standard procedures for inventorying and inspecting SMW facilities. This leads to the development of a responsive maintenance program to sustain BMP performance, and also includes functional and visual enhancements to upgrade SWM to the today's standards. SHA researches SWM facilities performance through monitoring and research studies. SHA continues development data management technology to manage and utilize BMP data more efficiently. Tools are being developed to facilitate timely decisions on remedial actions, and meet NPDES permit requirements.

The SHA Business Plan goes beyond the NPDES permit jurisdiction by promoting the statewide inventory and a high-level of BMPs performance. The goal is to bring 90 percent of all SHA owned SWM facilities to their functionality by FY 2012. Currently 84.9 % of SHA inventoried facilities function as designed. Figure 3-17 summarizes the progress.

SWM Facilities Program has shown environmental stewardship in the areas of innovative state-of-the-art inspection and data management technology as well as BMP remediation techniques. The program components and structure demonstrate strategic approach to meet the NPDES Permit requirements and enhance the performance efficiency of SWM facilities to improve water quality in the sensitive watersheds of Chesapeake Bay.

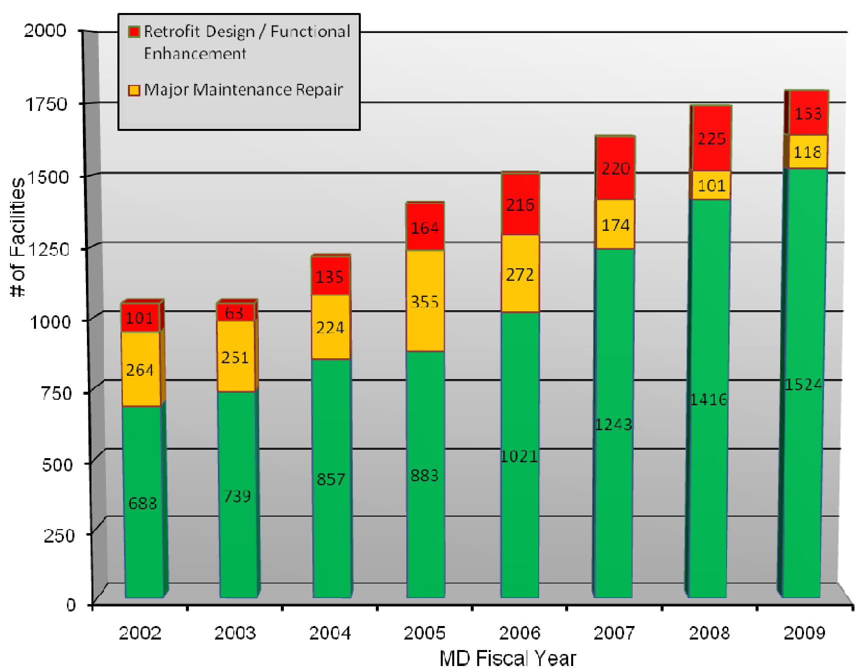


Figure 3-17 Progress in SWM Facilities Program

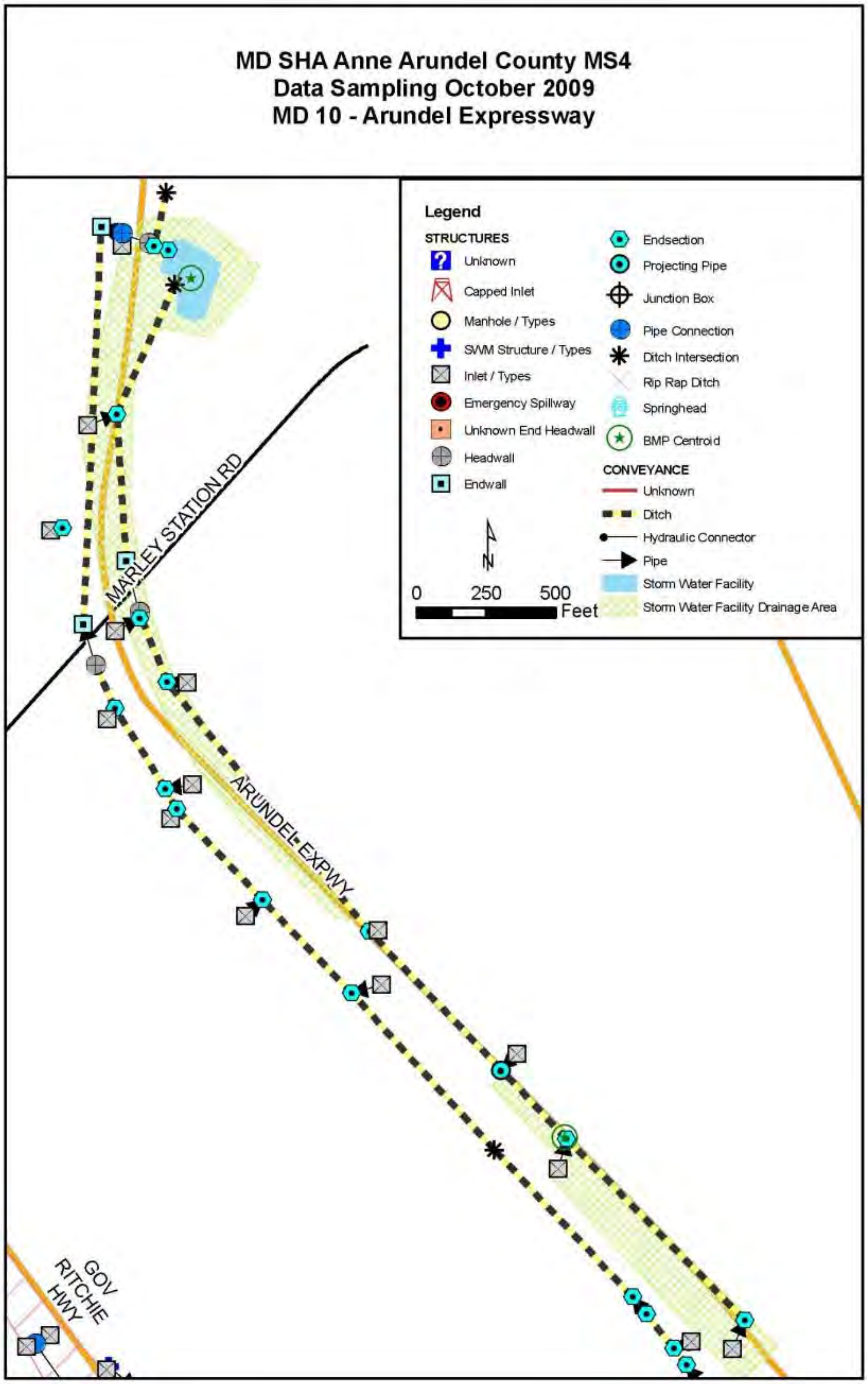
APPENDIX A:

Examples of Source Identification

Anne Arundel County
Baltimore County
Howard County
Prince George's County

SOURCE ID EXAMPLES

SOURCE ID EXAMPLES



Anne Arundel County Source ID Example

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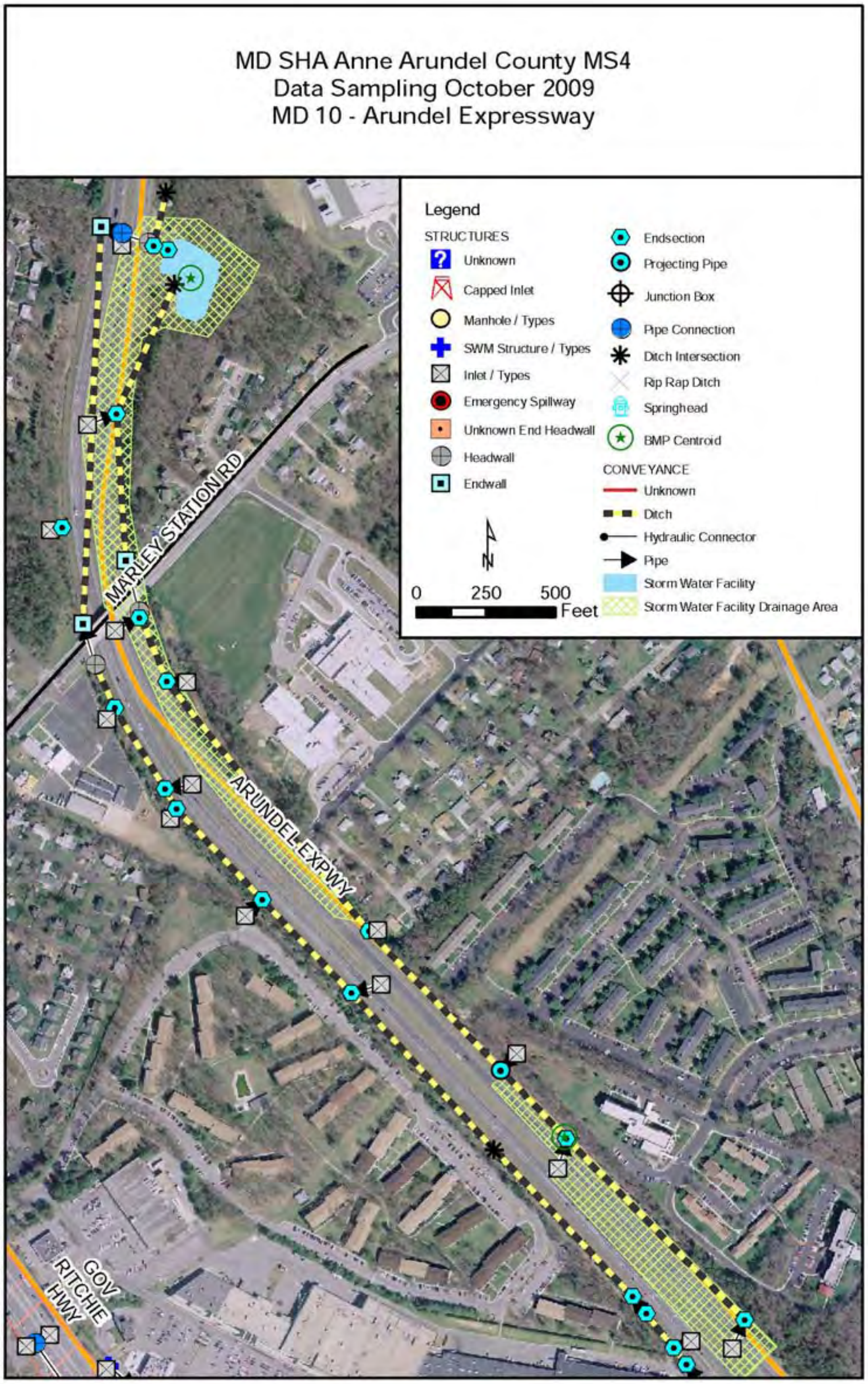

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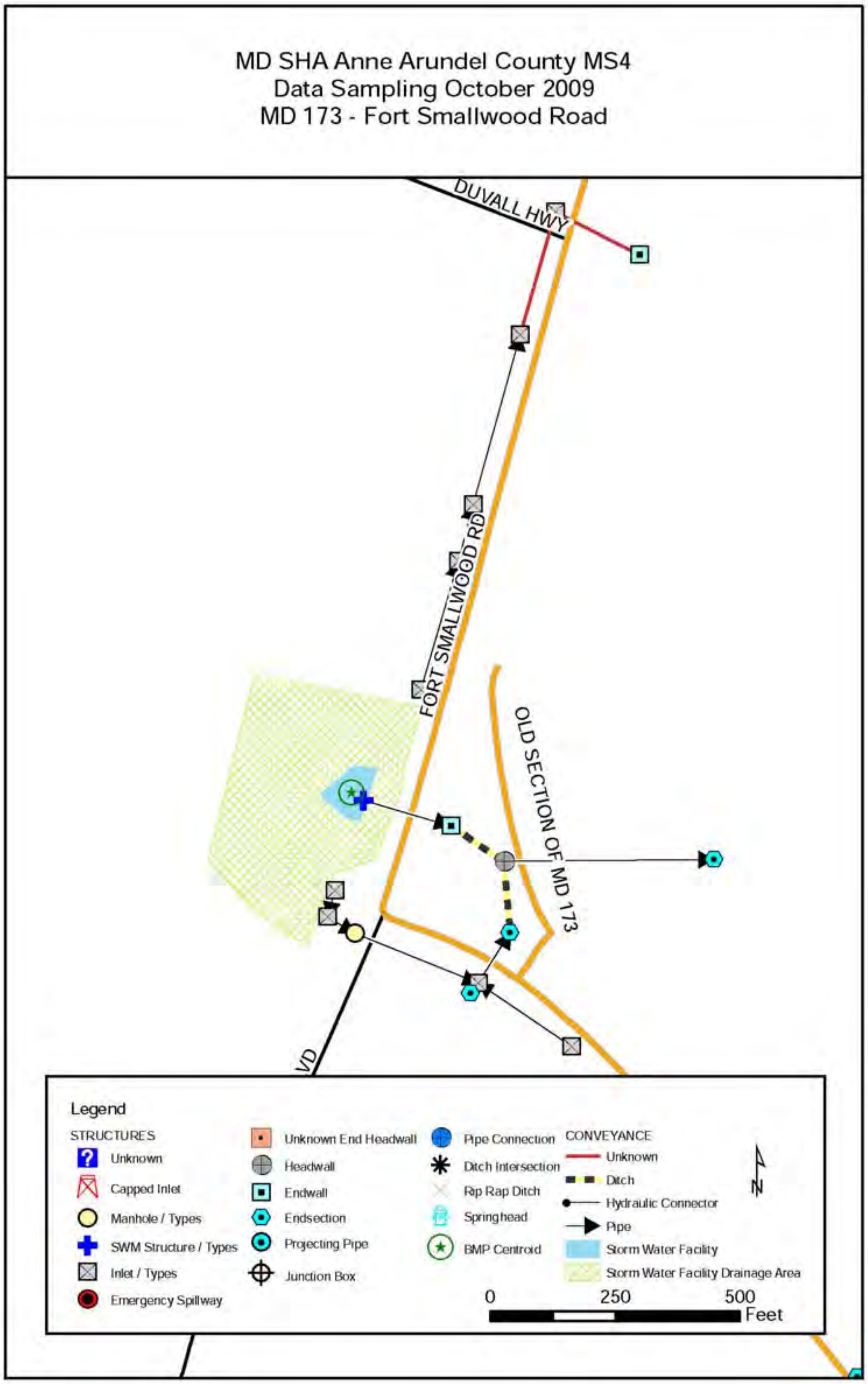

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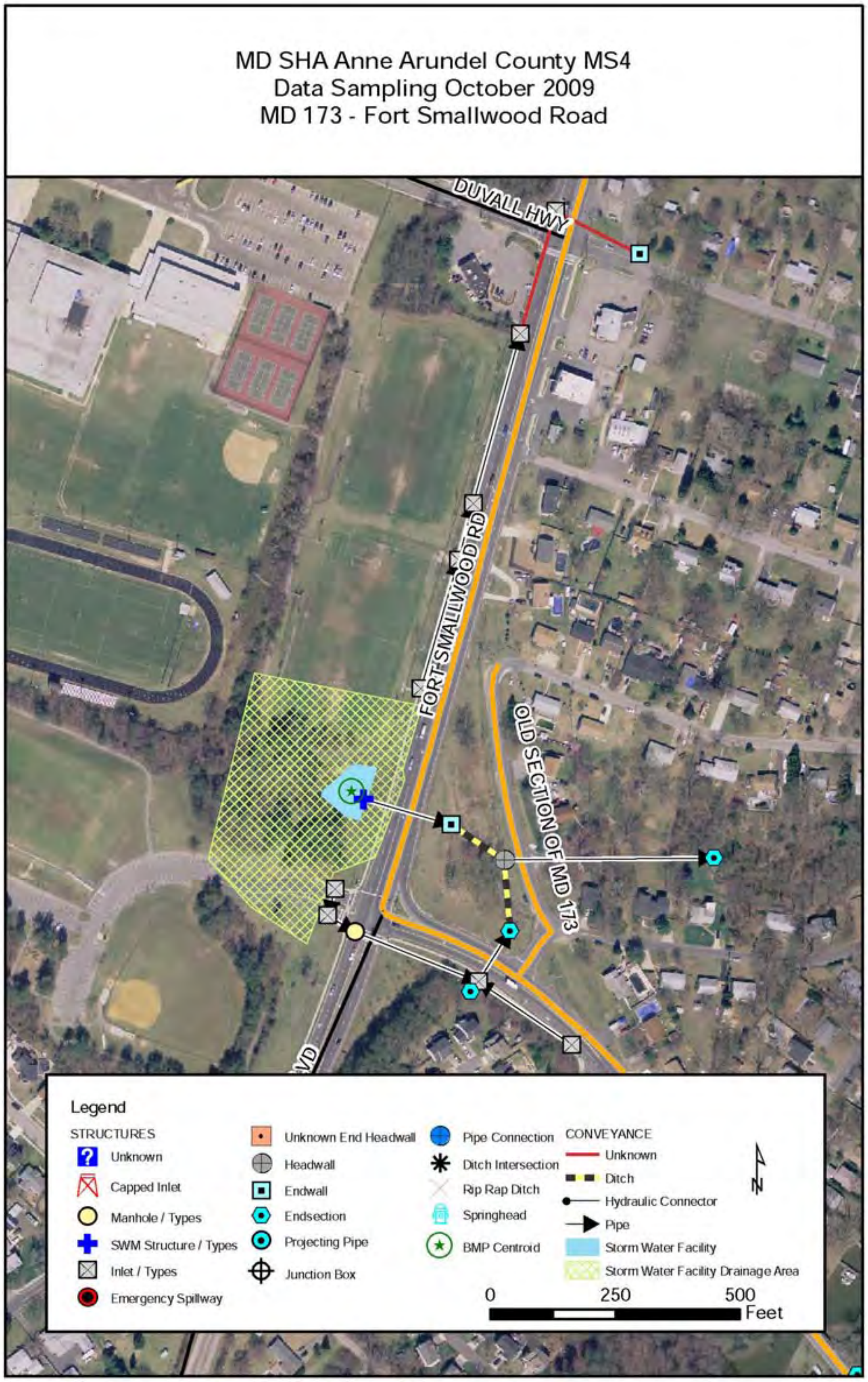

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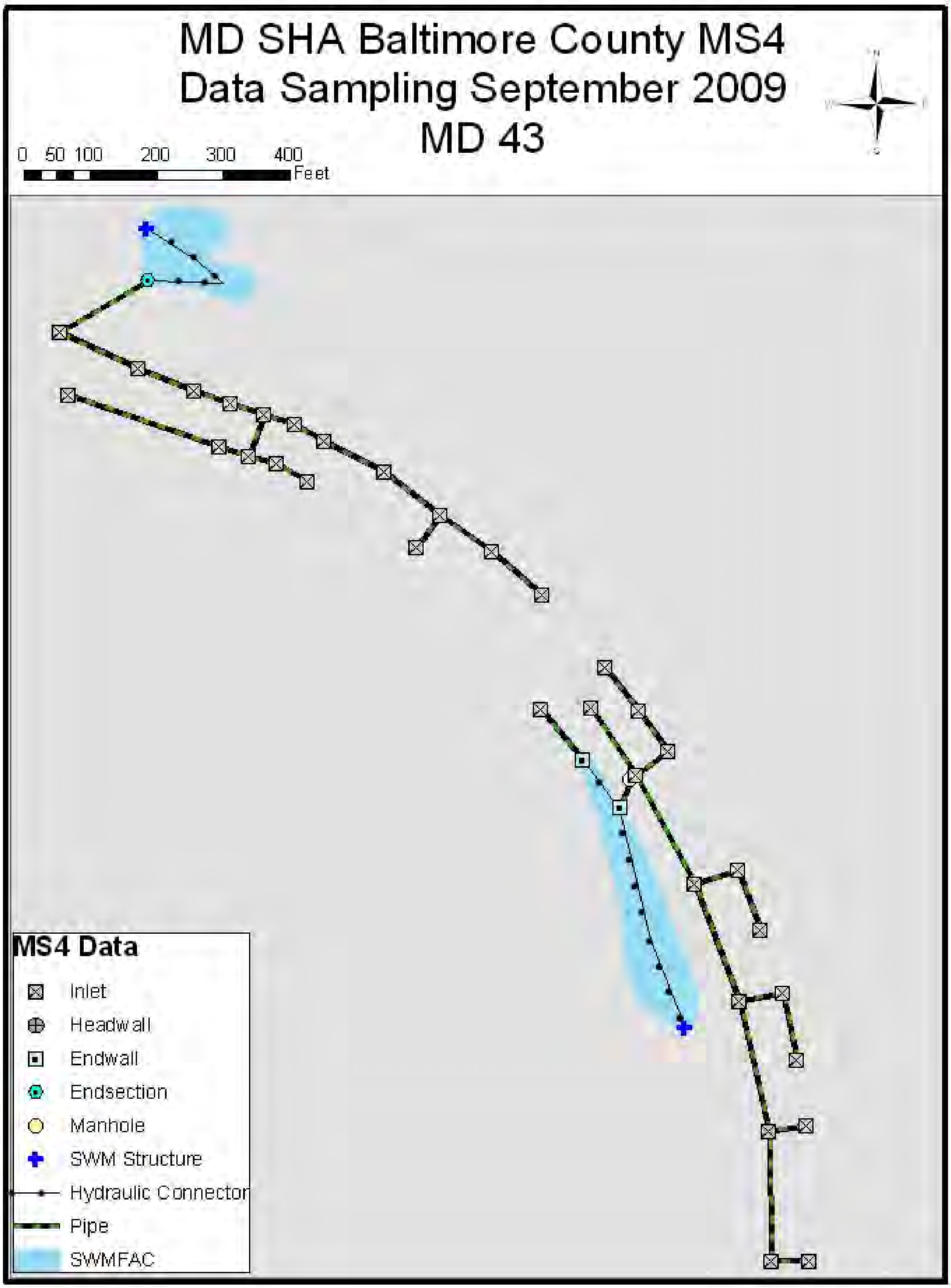
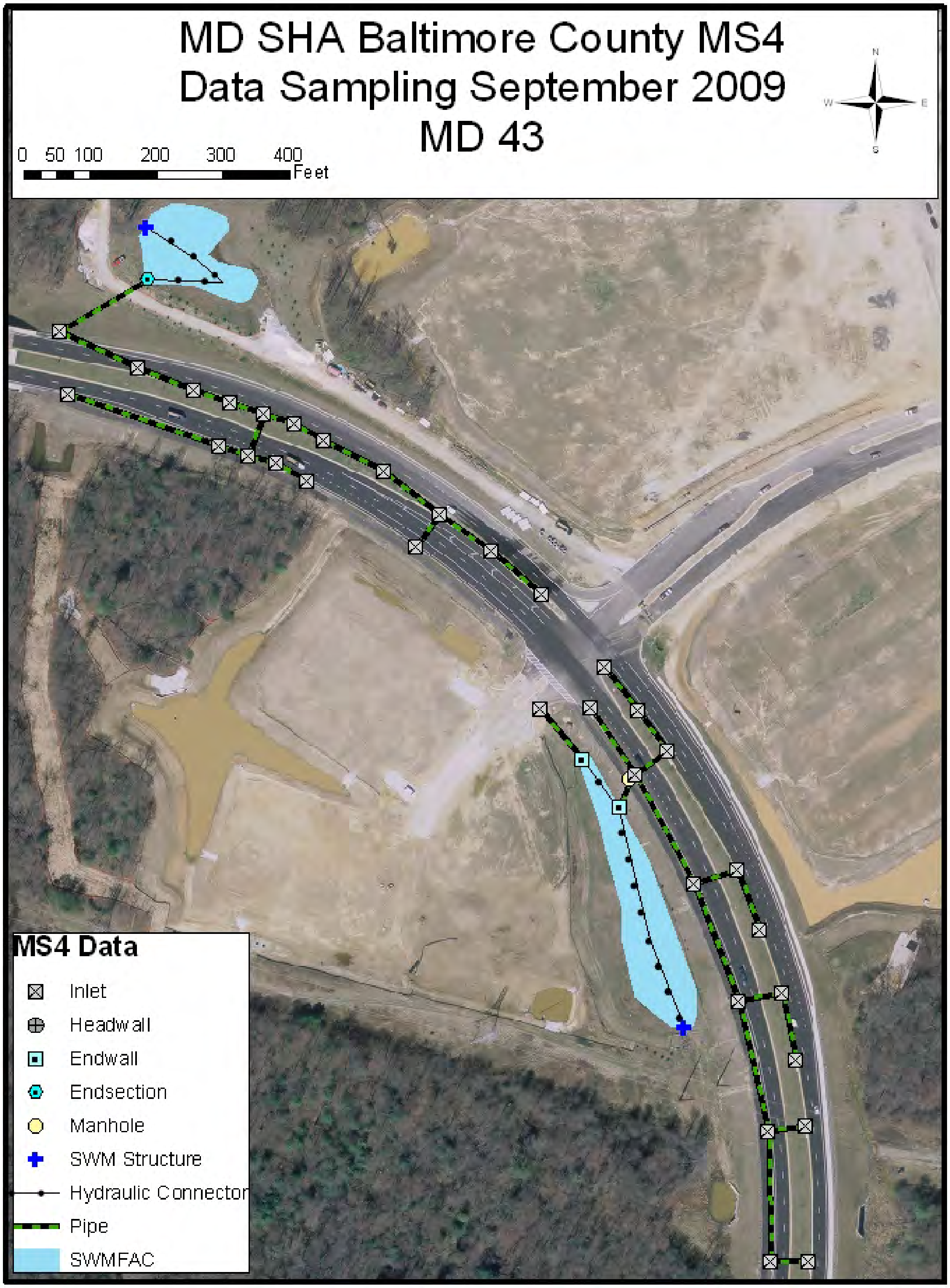


Baltimore County Source ID Example

SOURCE ID EXAMPLES



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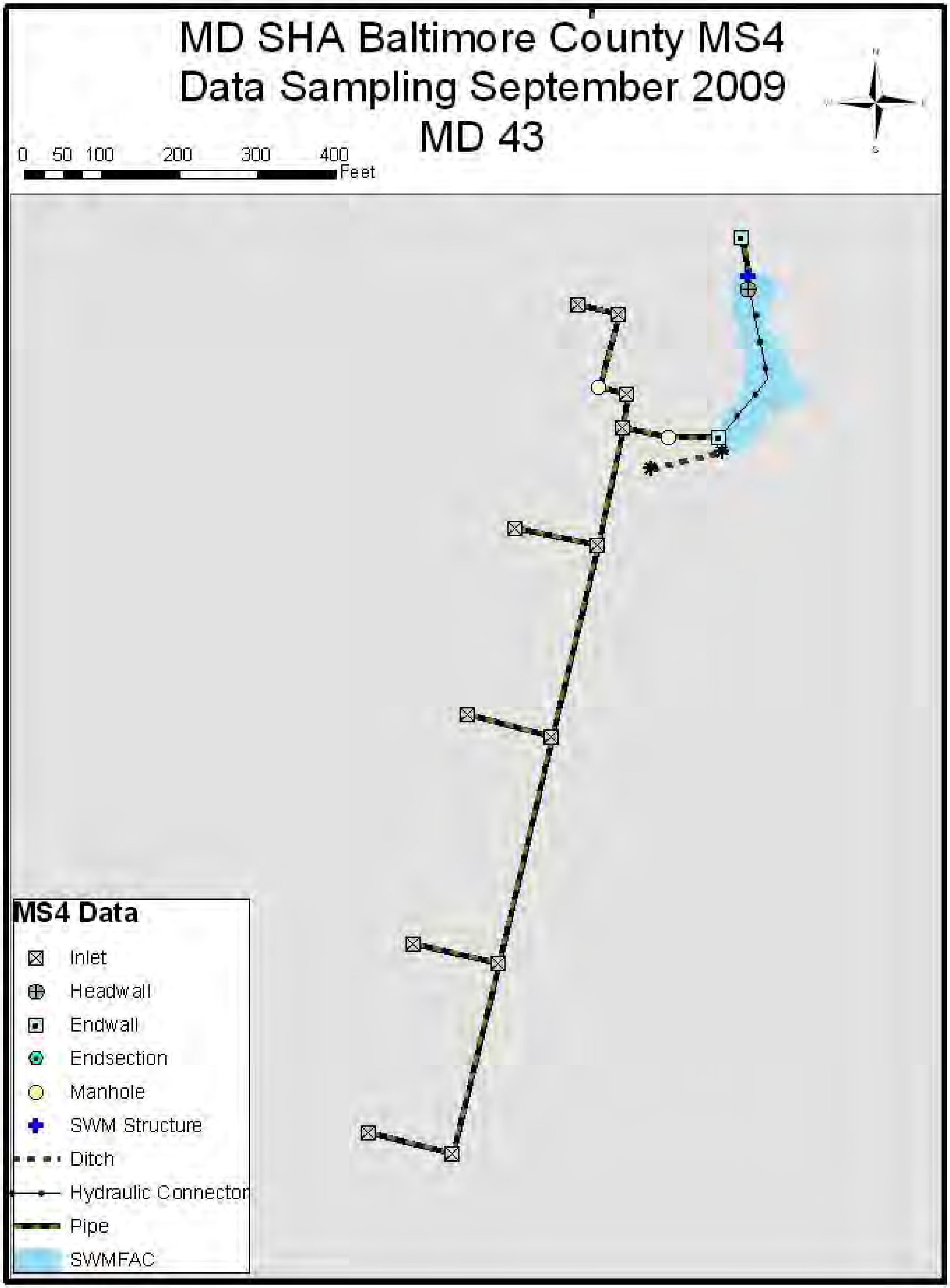

Baltimore County Source ID Example

SOURCE ID EXAMPLES

Baltimore County Source ID Example

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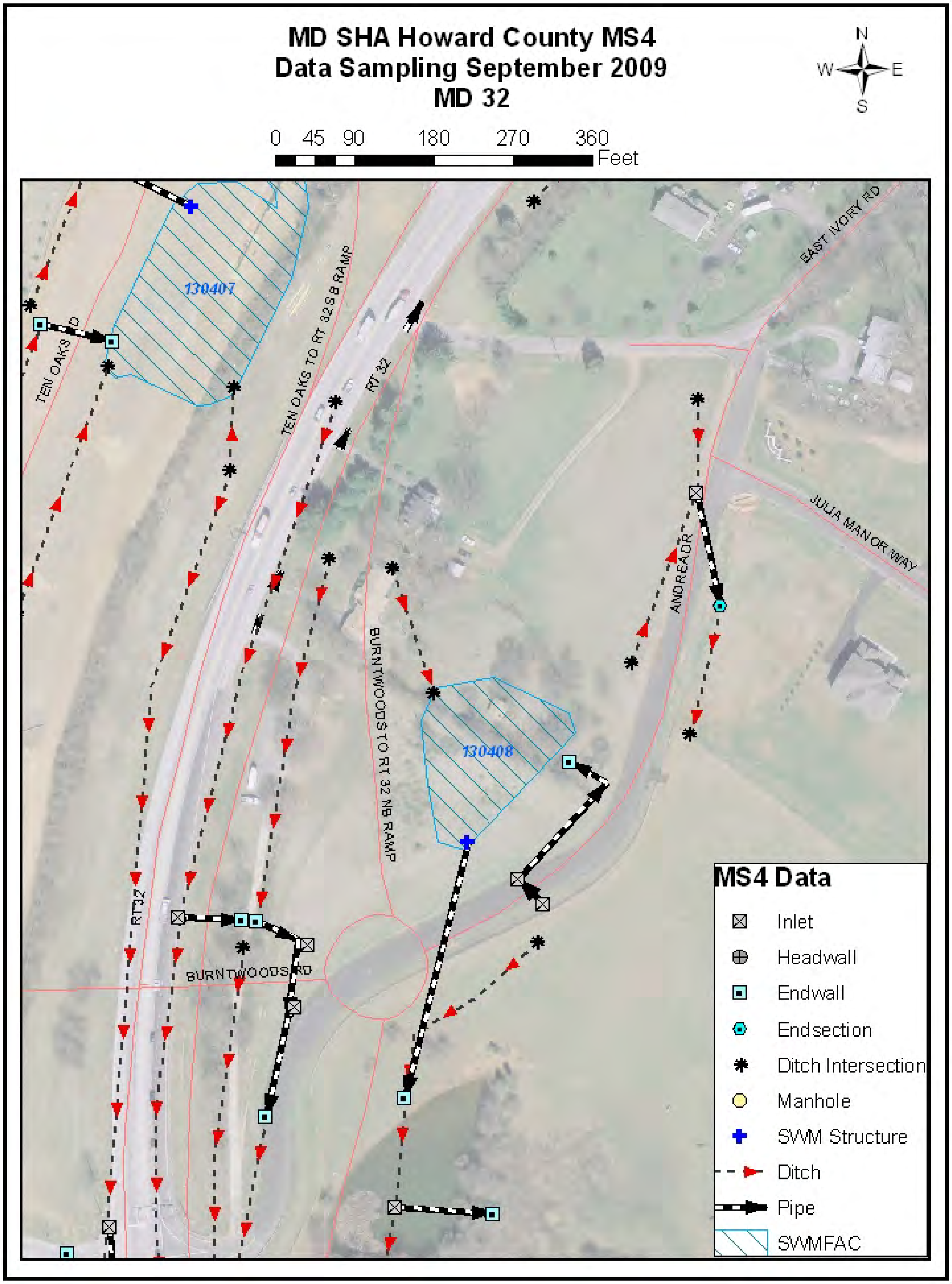

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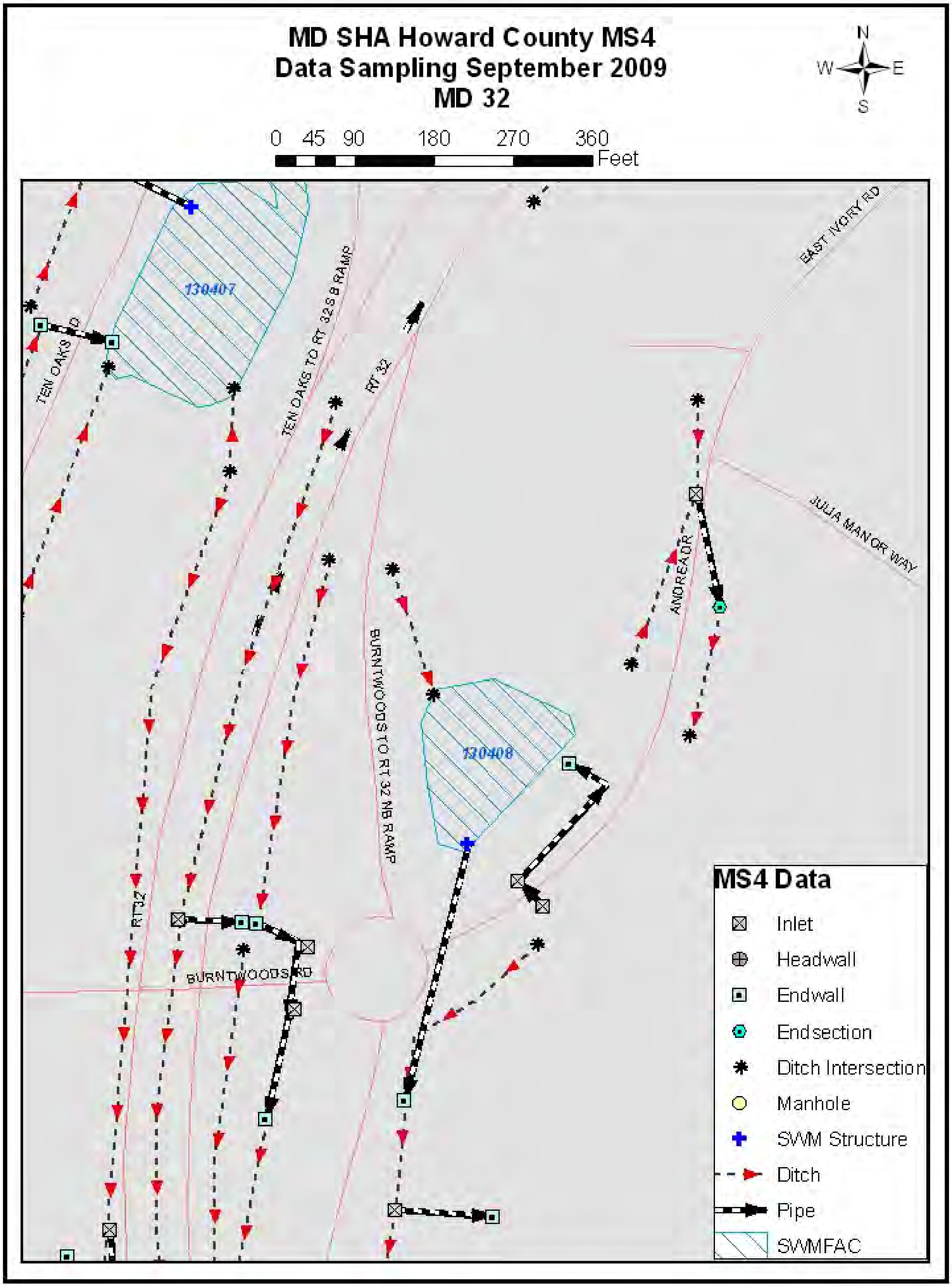

Howard County Source ID Example

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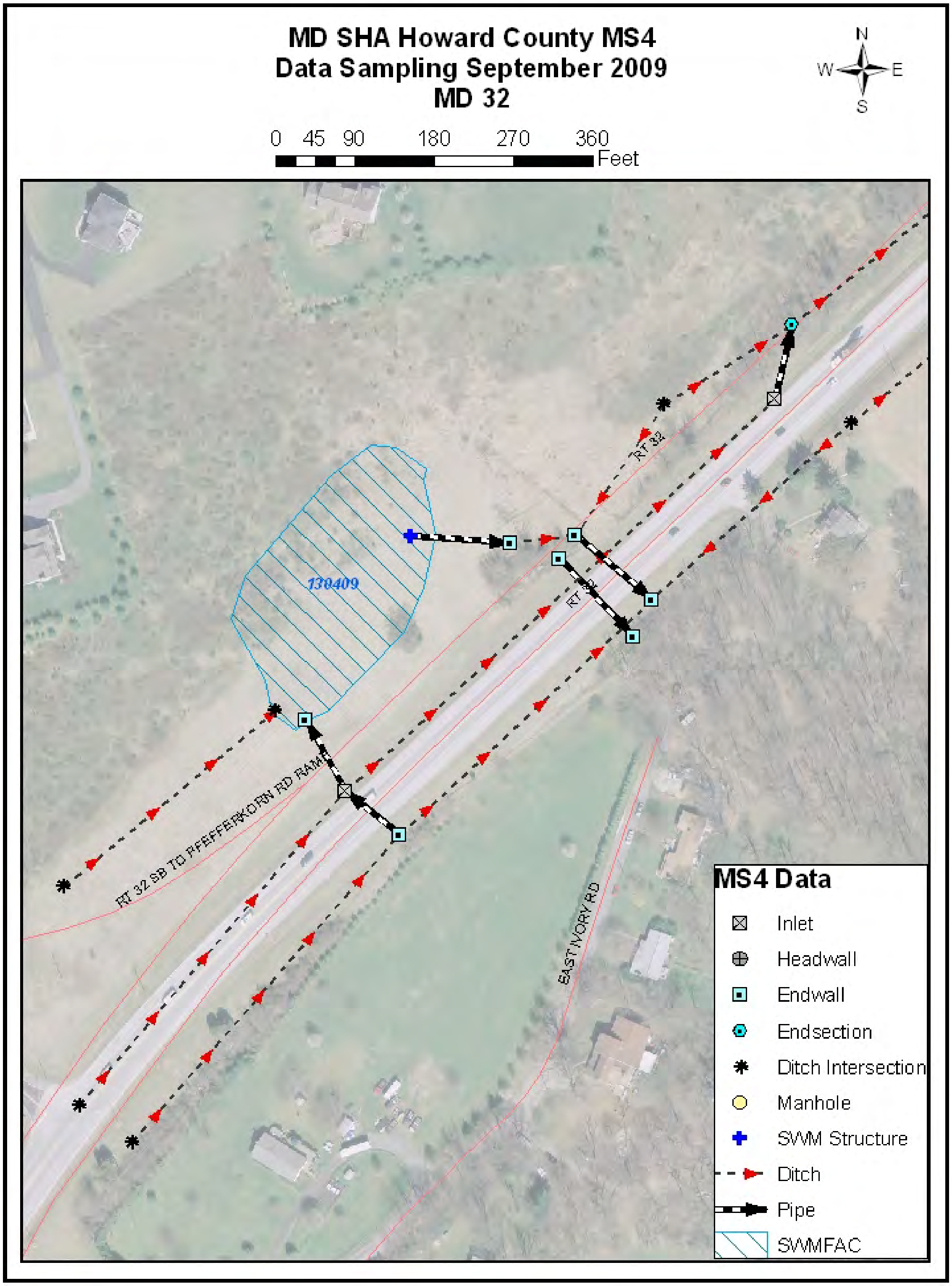

Howard County Source ID Example

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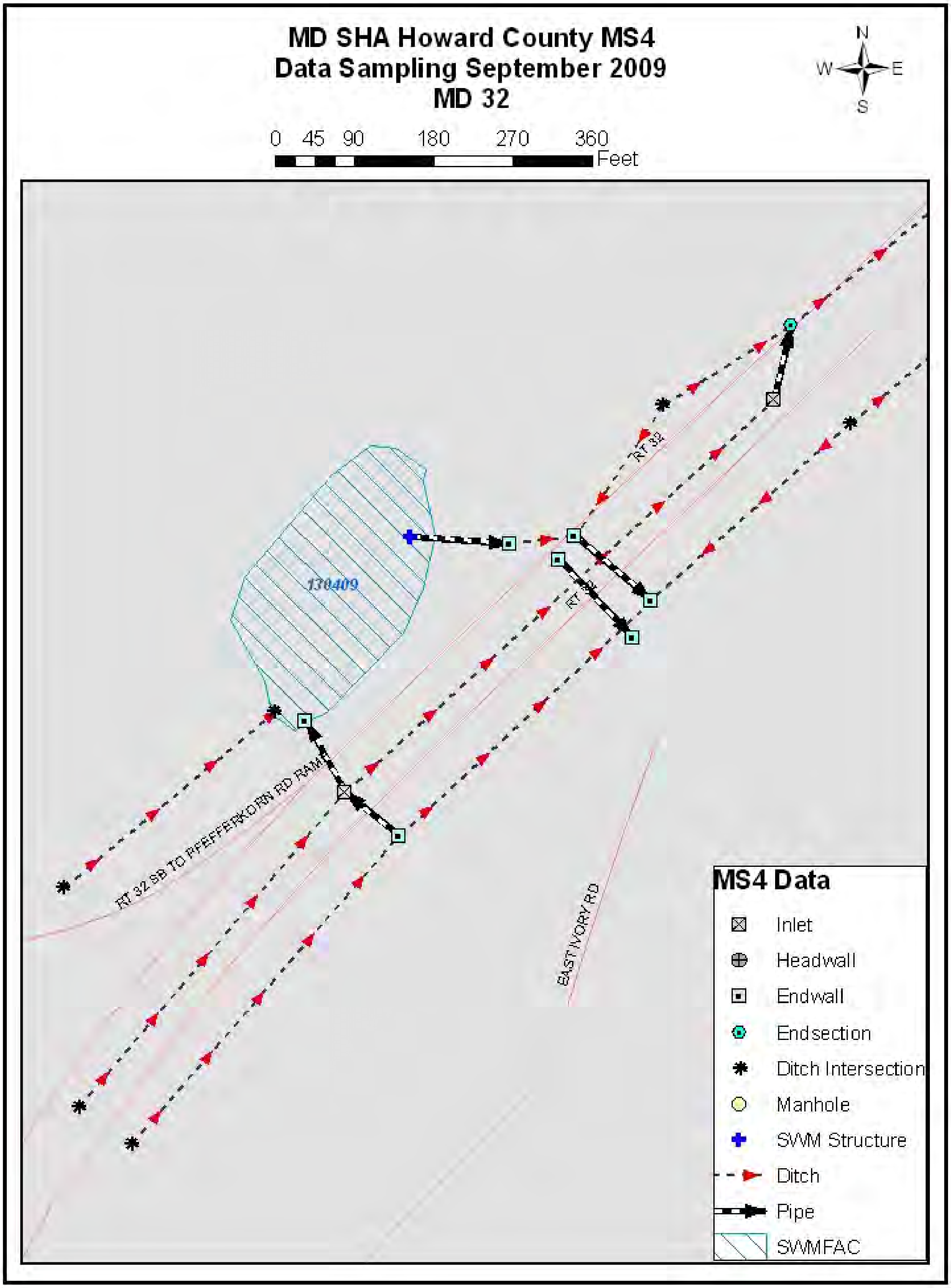

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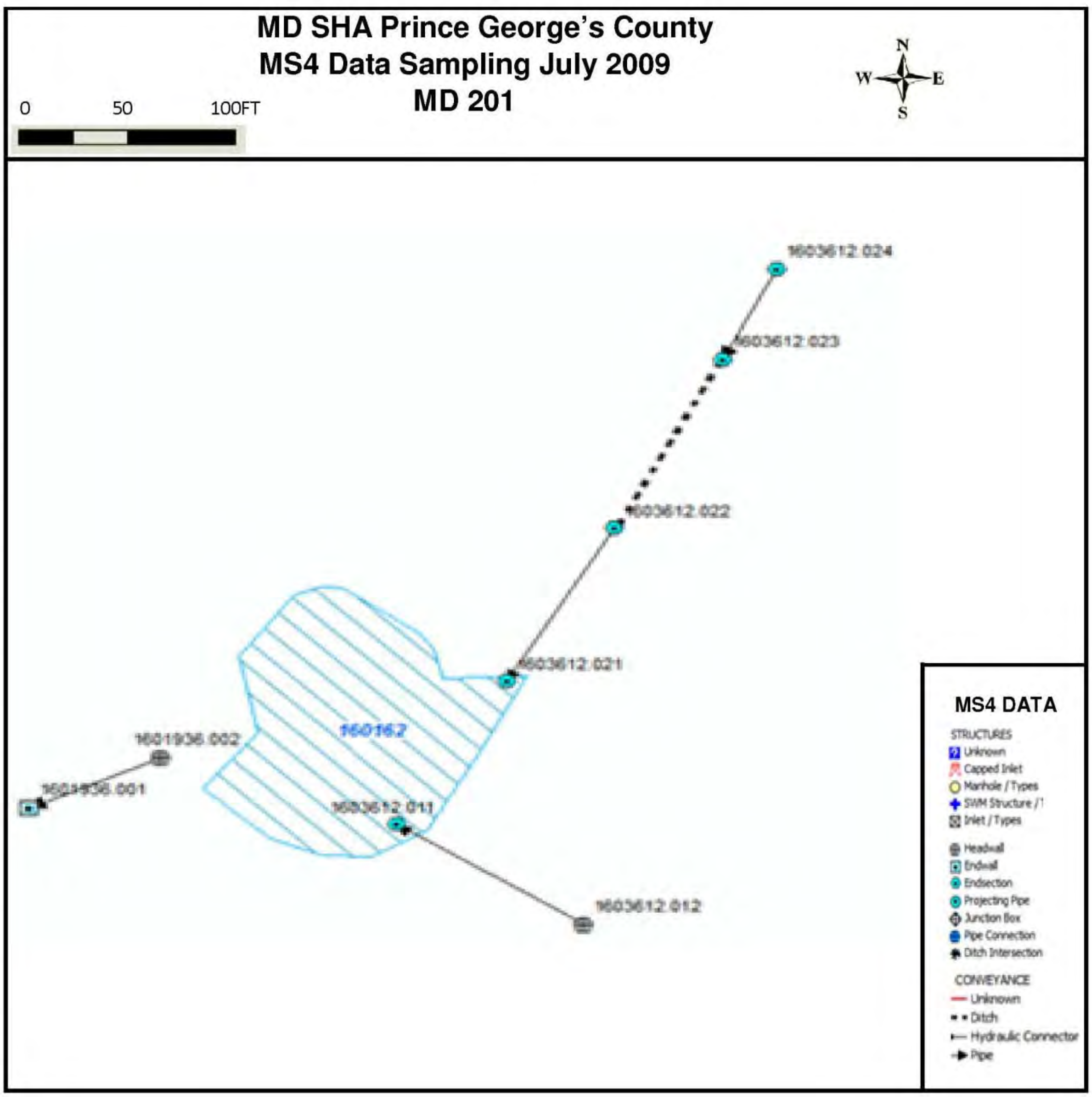
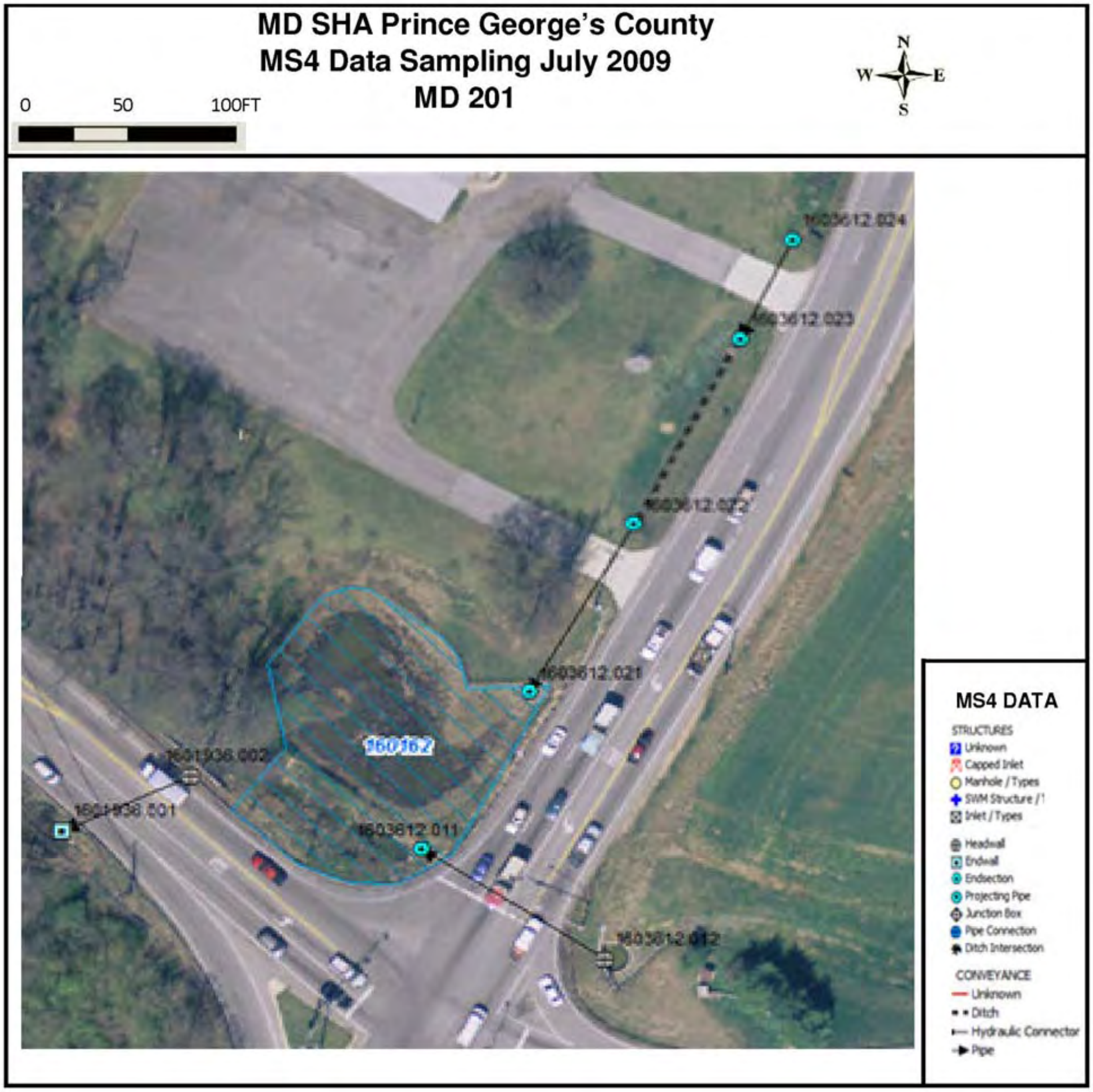


Prince George's Source ID Example

SOURCE ID EXAMPLES



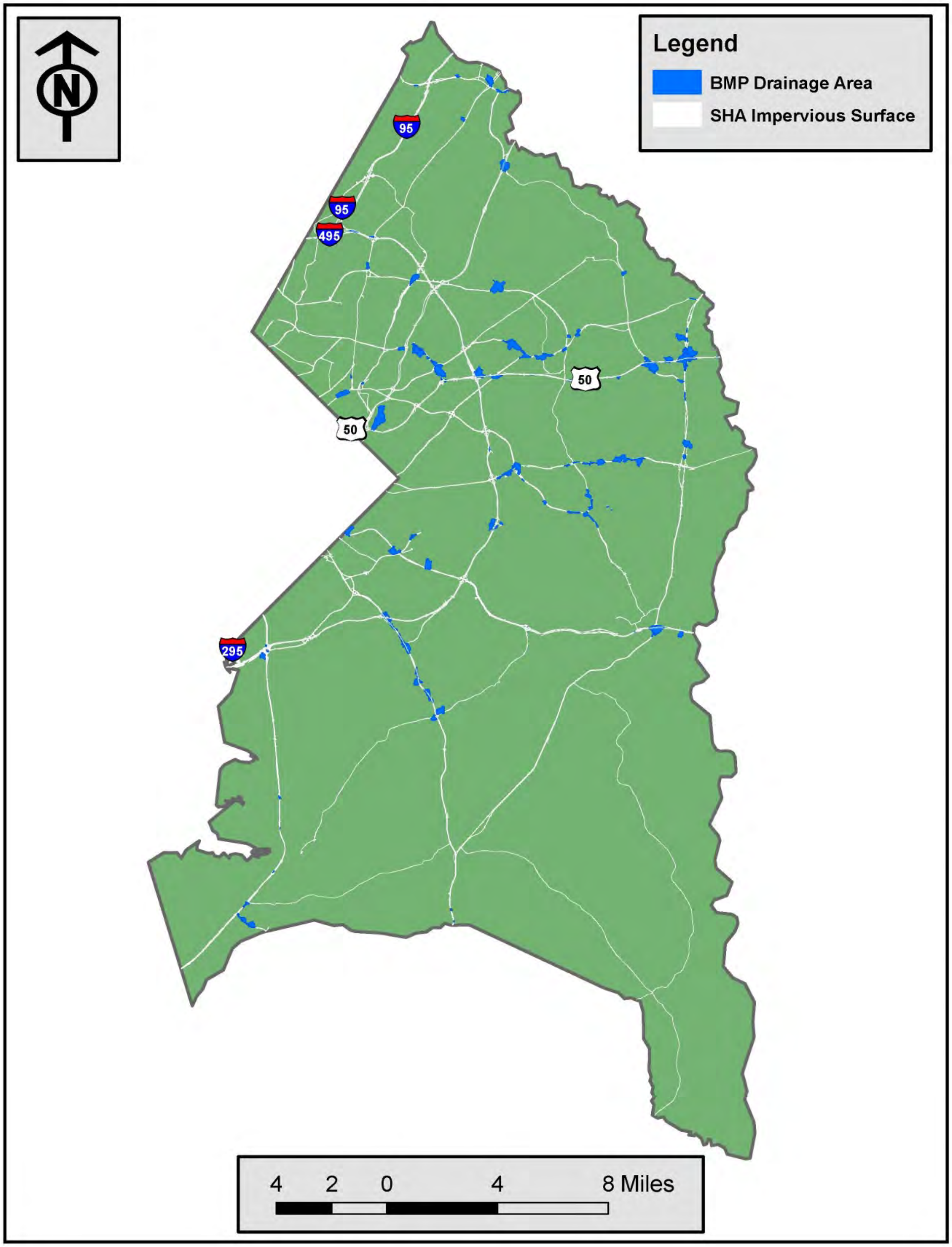
Prince George's Source ID Example

APPENDIX B:

Examples of Impervious Layers

Prince George's County

EXAMPLES OF IMPERVIOUS LAYERS



Prince George's County Impervious Layer

EXAMPLES OF IMPERVIOUS LAYERS

APPENDIX C:

Field Evaluation of Water Quality Benefits of Grass Swale for Managing Highway Runoff

Progress Report
July 24, 2009

Progress Report: Field Evaluation of Water Quality Benefits of Grass Swale for Managing Highway Runoff

Project Duration: February 2009 – July 2009

Project Sponsor: Maryland State Highway Administration (SHA)

Project Coordinators:
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Date: July 24, 2009

Executive summary

Water pollution caused by storm water runoff from paved areas and road ways has been increased drastically as urbanization and land development proceed rapidly. Due to relatively easy design and maintenance coupled with cost effectiveness and aesthetic benefits, grass swales have been adapted by the Maryland State Highway Administration (SHA) as Low Impact Development (LID) technologies to address roadway stormmwater runoff management. However, few data and references are available to prove the performance and efficiency of grass swale in terms of water quality as well as hydrologic benefits. Two individual swales were constructed in the median of a four-lane (two in each direction) on Maryland Route 32 near savage, Maryland, to treat runoff from the southbound roadway lanes. Four different storm events were monitored during April to July 2009 at three different sampling point; direct channel, a swale with pretreatment area (MDE swale), and a swale without pretreatment area (SHA swale). Event mean concentrations (EMCs) of most contaminants from swales were lower than EMCs from direct channel except Cl^- from both swales on both June 3rd and July 1s, TSS from MDE swale on June 3rd, and NO_2^- from MDE swale on June 3rd. The water quality results during the sampling period demonstrate that grass swales can be efficient in treating highway storm water runoff as LID technologies with hydrologic benefits, especially with unsaturated soil condition.

TABLE OF CONTENTS

Introduction 1

Materials and Methods 3

Results and Discussion 6

References 9

Appendix 1. Water Quality Data of outflow samples from Direct channel, MDE swale, and SHA swale 10

Appendix 2. Flow charts with rainfall graphs 14

Appendix 3. Swale Site photos 18

LIST OF TABLES

Table 1. Design parameters for MDE, SHA swales and direct channel 2

Table 2. Sampling times for storm 4

Table 3. Summary of the Analytical Method and detection limit for each analysis 5

Table 4. EMC of each storm event during the monitoring study..6

Table 5. Total mass of each contaminant discharged to drainage and percent removal efficiency of each swale compared to direct channel for (a) June 3rd Storm event and (b) July 1st Storm event 8

LIST OF FIGURES

Figure 1. Pollens from storm water runoff on April 29th; (a) Pollen in direct channel, and (b) Pollens in the first flush sample 6

Figure 2. Bare spots on pretreatment area of MDE swale....................7

Figure 3. Captured suspended solids on grass fiber filter (a) from MDE swales, and (b) from direct channel 7

Figure 4. Flow chart with rainfall graph for April 29th storm event....................14

Figure 5. Flow chart with rainfall graph for May 16th storm event....................15

Figure 6. Flow chart with rainfall graph for May 16th storm event....................16

Figure 7. Flow chart with rainfall graph for July 1st storm event....................17

Figure 8. Surface condition of the sampling points of; (a) MDE swale with some bare spots, and (b) SHA swale with well vegetated surface....................18

Figure 9. Check dam for; (a) MDE swale, and (b) SHA swale....................19

Figure 10. Pits caused by erosion near direct channel 20

Introduction

Stormwater runoff is a major contributor to water pollution in the United States (Line et al., 1996; Wu et al., 1998). Specifically, water pollution caused by storm water runoff from paved areas and road ways has been increased drastically as urbanization and land development proceed rapidly. Furthermore, the urbanization and land development have increased impervious areas and reduced vegetation, and therefore, worsen water quality due to altered hydrology of runoff flow.

Due to relatively easy design and maintenance coupled with cost effectiveness and aesthetic benefits, grass swales have been adapted by the Maryland State Highway Administration (SHA) as Low Impact Development (LID) technologies to address stormmwater runoff management by water filtration, evapotranspiration and infiltration through grass and soil. However, few data and references are available to prove the performance and efficiency of grass swale in terms of water quality as well as hydrologic benefits. Therefore, field monitoring for grass swales is needed to monitor water quality and hydrologic characteristics of swales.

Two individual swales were constructed in the median of a four-lane (two in each direction) high way on Maryland Route 32 near savage, Maryland (near Exit 38A of I-95N), to treat runoff from the southbound roadway lanes. The first swale (the one to the south) was constructed based on Maryland Department of the Environment (MDE) guidelines, while the second swale known as the SHA swale was identically constructed but without the pretreatment area.

Three sampling points; discharge from both swales as well as one direct concrete channel, which had essentially identical roadway drainage areas, were previous monitored by Stagge (2006) and Eluziea Jamil (2009). The concrete channel that collects runoff directly from the highway was constructed south of the swales in order to obtain instantaneous flow input and water quality from the highway surface and compare it to swale performance. Specific design parameters for the swales and direct concrete channel are shown in Table 1. More detailed information regarding the grass swale site can be found in Stagge (2006) and Eluzieal Jamil (2009).

Table 1. Design parameters for MDE, SHA swales and direct channel (partially adapted from Eluzieal Jamil, 2009).

	Direct	MDE Swale with Check Dams	SHA Swale with Check Dams
Roadway Area (ha)	0.271	0.225	0.224
Swale Area (ha), As	0	0.431	0.312
Total Area (ha), AT	0.271	0.656	0.393
Channel Material	Concrete	Grass	Grass
Channel Slope	0.2%	1.2%	1.6%
Channel Length (m)	168	137	198
Pretreatment Slope	-	6%	-
Pretreatment Width (m)	-	15.2 *	-
Number of Check Dam Rows	-	3	3
Thickness of each check dam (m)	-	0.914	0.914
Bottom width of Check Dam (m)	-	0.610	0.610
Total width of Check Dam (m)	-	variable	variable
Distance between two check dams (m)	-	60.5	59.8

* from roadway to channel center

This research is a extended study of the two previous filed monitoring research studies on the two grass swales. In this research, ten different water quality parameters as major pollutants in roadway runoff; Total Suspended solids (TSS), NO_3^-, NO_2^-, Total Kjeldahl Nitrogen (TKN), Total Phosphorus (TP), Cl^- and heavy metals including lead (Pb), copper (Cu), zinc (Zn), and cadmium (Cd) were measured and analyzed from the samples collected from all three sampling points. Precipitation and runoff flow data were also collected and analyzed to monitor hydrologic characteristics and performance of the swales.

Materials and Methods

Four different storm events were monitored during April to July 2009 (on April 29th, May 16th, June 3rd, and July 1st 2009) at three different sampling points; direct channel, discharge of swale with pretreatment area (MDE swale), and swale without pretreatment area (SHA swale).

During the storm events, rainfall was measured with 0.0254 cm sensitivity using a rain gauge (ISCO 674 Tipping Bucket Rain Gauge) and the data were recorded in 2 minute increments. Runoff flow from each sampling point was measured by an ISCO 730 bubbler flow module installed at a 125° V-notch wooden weir located at the end of each swale and the concrete channel. A tubing line connected to the bubbler flow module was installed at the bottom end of the V-notch to measure the water head level and the flow data were recorded by each sampler.

ISCO Model 6712 Portable Samplers were used in each sampling point with twenty-four 300 mL glass bottles installed inside. Sampling was triggered by water level at the V-notch greater than 0.254 cm (0.1 inch) and sampling was performed based on sampling times as shown in Table 2

Table 2. Sampling times for storm events (adapted from Eluzieal Jamil, 2009)

Sampling bottle ID	Direct (Time from start)	Both Swales (Time from start)
1, 2	zero minutes	zero minutes
3, 4	20 minutes	20 minutes
5, 6	40 minutes	40 minutes
7, 8	1 hour	1 hour
9, 10	1 hr 20 min	1 hr 20 min
11, 12	2 hr	1 hr 40 min
13, 14	2 hr 40 min	2 hr
15, 16	3 hr 20 min	2 hr 20 min
17, 18	4 hr 20 min	2 hr 40 min
19, 20	5 hr 20 min	3 hr 40 min
21, 22	6 hr 20 min	4 hr 40 min
23, 24	8 hr	6 hr

As soon as sampling was completed from each sampling point, all samples were collected (within 24 hours) and transported to the University of Maryland Environmental Laboratory for water quality analysis. Nutrients analyses including NO_3^-, NO_2^- and TP, and TSS were immediately measured. The samples were filtered through 0.2 μm membrane filter to analyze NO_3^-, NO_2^- and Cl^-. Around 100 mL of sample was preserved for metal analyses using six drops of concentrated trace level HNO_3 and a 200 mL sample was preserved for TKN analysis using 12 drops of concentrated H_2SO_4.

Heavy metal concentrations (Pb, Cu, Cd, and Zn) of the samples were measured using flame or graphite furnace atomic absorption spectrophotometry (Perkin Elmer 5100PC with Perkin Elmer Zeeman Furnace module 5100ZL) after nitric acid digestion of samples. Analytical methods used in this study are summarized in Table 3.

Table 3. Summary of the Analytical Method and detection limit for each analysis (Adapted from Eluzieal Jamil, 2009)

Pollutant	Standard Method (APHA et al. 1995)	Detection Limit (mg/L)
Total Suspended Solids (TSS)	2540 D	1
Total Phosphorus (TP)	4500-P	0.025
Total Kjeldahl Nitrogen (TKN)	4500-N0rg	0.14
Copper	3030 E	0.005
Lead	3030 E	0.005
Cadmium	3030 E	0.0002
Zinc	3030 E	0.025
Chloride	Dionex DX-100 ion chromatograph	1
Nitrate	Dionex DX-100 ion chromatograph	0.05 as N
Nitrite	4500-NO2- B	0.005 as N

Results and Discussion

Event mean concentrations (EMC) of each contaminant from swale and direct samples for four monitored storm events are shown in Table 4. Two storm events, on April 29th and May 16th, did not produce outflow from both swales due to low rainfall (see figure 4 and 5 in Appendix 2: total 0.12 inch and 0.33 inch for April 29th and May 16th, respectively). One notable observation from direct samples collected from the April 29th storm is that a relatively high TKN EMC (9.3 mg/L –N) was observed in the direct runoff samples. The first flush sample, especially, demonstrated 21 mg/L –N TKN concentration. This high TKN likely originated mainly from high pollen content in runoff samples washed from roadways and air during the precipitation. High pollen content in runoff water through the direct channel during and after rainfall was observed (Figure 1a). Pollen in collected samples was also observed as shown in Figure 1b.

Table 4. EMC of each storm event during the monitoring study.

Storm Event	Sampling Point	Solids (mg/L)	Nutrients (mg/L)				Heavy metals (μg/L)				Cl^- (mg/L)
		TSS	NO_3^--N	NO_2^--N	TKN	TP	Pb	Cu	Zn	Cd	Cl^-
April 29	Direct	139	0.65	0.18	9.3	0.54	17	60	320	0.4	NA
	MDE	No outflow									
	SHA	No outflow									
May 16	Direct	68	1.05	0.03	1.4	0.39	11	32	250	0.2	56
	MDE	No outflow									
	SHA	No outflow									
June 3	Direct	145	0.76	0.04	3.7	0.99	21	64	650	1.0	16
	MDE	**162**	0.34	**0.05**	1.9	0.36	21	18	24	0.2	**45**
	SHA	45	0.38	0.02	1.9	0.24	6.5	10	45	0.5	**29**
July 1	Direct	183	0.67	0.03	6.8	1.1	19	48	1200	0.9	26
	MDE	80	0.36	0.03	1.5	0.20	9.5	9.0	28	0.2	**127**
	SHA	15	1.95	0.04	2.2	0.28	4.8	8.1	16	0.3	**65**

Figure 1. Pollens from storm water runoff on April 29th; (a) Pollen in direct channel, and (b) Pollens in the first flush sample.

EMCs of most contaminants from the swales were lower than EMCs from the direct channel, except for Cl^- from both swales on both June 3rd and July 1st, TSS from the MDE swale on June 3rd, and NO_2^- from the MDE swale on June 3rd, as indicated in bold in Table 4. The higher EMC of Cl^- from both swales is likely due to salt accumulation on the swales by salt application on roadways for deicing during winter seasons. The salts are captured by the swales during storm events and the accumulated salts are slowly released during later storm events. Therefore, the swales perform as buffers to release salts gradually, which prevents sudden and significant increase of Cl^- concentrations in water bodies during winter season.

The higher TSS EMC from the MDE swale on June 3rd is probably due to intense rainfall and some bare spots on the pretreatment area as shown in Figure 2. Most of the TSS in the MDE swale samples likely originated from soils and clays which were washed and mobilized during intense storm events. This was observed by comparing captured total suspended solids by grass fiber filter from MDE swales with that from direct channel (Figure 3).

Figure 2. Bare spots on pretreatment area of MDE swale.

Figure 3. Captured suspended solids on grass fiber filter (a) from MDE swales, and (b) from direct channel.

Table 5 indicates total mass of each contaminant discharged to drainage and percent removal in mass by swales. As shown in bold in Table 5, mass of some contaminants was higher from the swales than the direct channel. Furthermore, some contaminants show higher release from swales than direct channel, although the EMCs of the contaminants from swales were lower than that from the direct channel. This is because higher flows from both swales were produced than that from the direct channel, due to the greater total water receiving areas, including pretreatment areas, as well as saturated soil conditions on June 3rd (Figure 6 in Appendix 2).

Table 5. Total mass of each contaminant discharged to drainage and percent removal efficiency of each swale compared to direct channel for (a) June 3rd Storm event and (b) July 1st Storm event

(a) June 3rd Storm event

Total Mass discharged		Nutrients (g)				TSS (kg)	Cl^- (kg)	Heavy metals (g)			
		NO_2^--N	NO_3^--N	TKN-N	TP	TSS	Cl^-	Zn	Cu	Pb	Cd
Direct	Mass	7.2	133	642	174	25.5	2.8	115	11.3	3.6	0.17
MDE	Mass	**14.6**	122	605	116	**51.9**	**14**	7.8	5.6	**6.7**	0.077
	% Removal	**-103***	8.5	5.9	33.0	**-1037**	**-407**	93.2	50.1	**-83.5**	55.4
SHA	Mass	**10.7**	**181**	**1026**	127	24.0	**15**	24	5.5	3.4	**0.25**
	% Removal	**-49.2**	**-35.5**	**-59.7**	26.7	5.9	**-444**	79.1	51.7	5.4	**-43.7**

(b) July 1st Storm event

Total Mass discharged		Nutrients (g)				TSS (kg)	Cl^- (kg)	Heavy metals (g)			
		NO_2^--N	NO_3^--N	TKN-N	TP	TSS	Cl^-	Zn	Cu	Pb	Cd
Direct	Mass	1.15	22.7	233	35.8	6.2	0.88	41	1.6	0.63	0.032
MDE	Mass	0.34	4.30	18.1	2.47	0.97	1.5	0.34	0.11	0.11	0.0019
	% Removal	70.1	81.1	92.2	93.1	84.3	**-73.3**	99.2	93.4	81.7	93.9
SHA	Mass	0.34	16.5	18.3	2.33	0.12	0.55	0.13	0.068	0.040	0.0022
	% Removal	70.3	27.6	92.1	93.5	98.0	37.8	99.7	95.8	93.6	93.0

* Negative percent removal indicates percent production (increase) of contaminants compared to that from direct channel.

Among the metals studied, zinc shows the greatest percent removal by the swales, while much higher Zn EMCs (ranging from 250 to 1200 µg/L) than Cu (32 to 60 µg/L), Pb (11 to 21 µg/L) and Cd (0.2 to 1.0) EMCs were observed from direct channel (Table 4). The percent removal of all the contaminants by the swales for July 1st storm was much greater than that for June 3rd (Table 5). This is because high unsaturated condition of swale soils on July 1st makes large portion of runoff flows infiltrate into soil. Therefore, significant decrease of outflows to drainage (see Figure 6 in Appendix 2) resulted less release of contaminants to water bodies.

The water quality results during the sampling period demonstrate that grass swales can be efficient in treating highway storm water runoff as LID technologies with hydrologic benefits, especially with unsaturated soil condition.

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APPENDIX 1. Water Quality Data of outflow samples from Direct channel, MDE swale, and SHA swale.

(a) April 29th Storm

Direct		Average Flow	Nitrite-N	Nitrate-N	TKN-N	TP	TSS	Chloride	Zinc	Copper	Lead	Cadmium
Bottles	*Sampling Date*	*(L/s)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	(mg/L)	(ug/L)	*(ug/L)*	*(ug/L)*	*(ug/L)*
1,2	4/29/09 8:56	0.94	0.298	1.11	21	1.362	549	NA	649.1	104.0	0.7	0.37
3,4	4/29/09 9:16	1.39	0.198	0.94		0.611	234	NA	407.5	70.1	40.5	0.52
5,6	4/29/09 9:36	1.91	0.171	0.73	6.72	0.677	147	NA	389.0	58.5	6.1	0.25
7,8	4/29/09 9:56	0.94	0.124	0.62		0.669	45	NA	337.0	55.6	36.4	0.62
9,10	4/29/09 10:16	1.27	0.245	0.37	2.8	0.219	43	NA	172.7	45.5	5.3	0.47
11,12	4/29/09 10:56	0.79	0.065	0.33		0.129	32	NA	93.2	51.0	6.5	0.41

(b) May 16th Storm

Direct		Average Flow	*Nitrite-N*	*Nitrate-N*	*TKN-N*	*TP*	*TSS*	*Chloride*	*Zinc*	Copper	Lead	Cadmium
Bottles	*Sampling Date*	*(L/s)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	*(mg/L)*	(mg/L)	(ug/L)	*(ug/L)*	*(ug/L)*	*(ug/L)*
1,2	5/16/09 21:28	3.85	0.170	0.52	7.98	0.740	569	55.25	1781.0	162.0	37.5	1.31
3,4	5/16/09 21:48	2.59	0.068	0.58		0.553	270	26.11	905.3	77.0	18.8	0.81
5,6	5/16/09 22:08	1.96	0.051	0.92	1.54	0.393	98	54.82	460.4	48.1	19.9	0.49
7,8	5/16/09 22:28	0.94	0.037	1.13		0.370	33	102.48	224.5	24.4	8.1	0.17
9,10	5/16/09 22:48	1.41	0.046	1.82	1.54	0.275	27	120.47	199.2	22.8	6.9	0.24
11,12	5/16/09 23:28	3.11	0.031	1.41		0.310	29	55.60	146.1	21.3	11.8	0.16
13,14	5/17/09 0:08	3.21	0.017	0.54	0.56	0.345	35	26.53	147.9	22.0	8.8	0.15
15,16	5/17/09 0:48	2.50	0.018	1.24		0.444	20	72.94	136.4	22.5	8.3	0.19
17,18	5/17/09 1:48	1.89	0.014	1.03	0.7	0.428	34	58.78	79.8	20.6	4.6	0.10
19,20	5/17/09 2:48	1.24	0.011	1.29		0.155	27	27.27	78.0	14.2	12.9	0.01
21,22	5/17/09 3:48	0.73	0.012	0.81	0.56	0.504	32	63.63	54.3	39.2	5.2	0.11
23,24	5/17/09 5:28	0.42	0.011	0.87		0.481	16	61.38	73.7	15.4	6.1	0.10

(c) June 3rd Storm

Direct		Average Flow	Nitrite-N	Nitrate-N	TKN-N	TP	TSS	Chloride	Zinc	Copper	Lead	Cadmium
Bottles	Sampling Date	(L/s)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
1,2	6/3/2009 20:10	9.60	0.204	1.92	3.36	0.272	136	15.0	655	176.4	19.7	0.59
3,4	6/3/2009 20:30	36.27	0.045	0.72		1.085	347	13.2	1362	137.4	51.2	1.44
5,6	6/3/2009 20:50	19.89	0.019	0.44	4.62	4.733	175	13.9	1168	46.9	26.2	1.32
7,8	6/3/2009 21:10	0.94	0.025	1.07		0.383	76	31.5	325	37.9	19.3	0.69
9,10	6/3/2009 21:30	2.14	0.027	1.06	1.31	0.222	30	29.2	188	50.0	10.1	0.33
11,12	6/3/2009 22:10	24.62	0.022	0.69		0.188	71	12.2	184	29.3	1.4	0.66
13,14	6/3/2009 22:50	6.62	0.019	0.49	5.88	0.232	131	9.1	915	44.7	20.3	1.61
15,16	6/3/2009 23:30	2.90	0.062	0.36		0.705	195	14.9	99	12.7	15.1	1.47
17,18	6/4/2009 0:30	1.49	0.007	0.61	0.42	0.099	31	21.1	67	16.0	10.5	0.13
19,20	6/4/2009 1:30	1.08	0.004	0.66		0.150	18	27.3	271	15.7	21.6	0.30
21,22	6/4/2009 2:30	0.69	0.004	0.63	3.5	0.075	12	28.8	111	16.1	9.5	0.15
23,24	6/4/2009 4:10	0.41	0.004	0.62		0.123	27	30.3	90	15.3	12.3	0.16

MDE Swale		Average Flow	Nitrite-N	Nitrate-N	TKN-N	TP	TSS	Chloride	Zinc	Copper	Lead	Cadmium
Bottles	Sampling Date	(L/s)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
1,2	6/3/2009 20:22	3.13	0.373	0.42	3.92	0.775	267	45.03	75.1	27.3	27.4	0.56
3,4	6/3/2009 20:42	89.47	0.024	0.6		0.683	279	48.48	46.0	23.9	31.6	0.39
5,6	6/3/2009 21:02	35.21	0.015	0.41	1.4	0.294	99	23.56	2.9	15.1	20.7	0.16
7,8	6/3/2009 21:22	6.27	0.014	0.23		0.176	28	35.55	1.3	9.7	14.6	0.13
9,10	6/3/2009 21:42	1.68	0.012	0.14	0.84	0.128	20	55.67	8.1	8.6	10.6	0.10
11,12	6/3/2009 22:22	2.26	0.010	0.21		0.193	35	97.14	2.9	7.6	8.8	0.05
13,14	6/3/2009 22:22	59.01	0.016	0.4	1.4	0.263	289	68.08	47.5	25.7	29.3	0.33
15,16	6/3/2009 22:42	42.94	0.008	0.36		0.205	102	17.99	1.4	14.7	15.3	0.12
17,18	6/3/2009 23:02	10.33	0.007	0.2	1.82	0.157	39	26.96	2.4	9.6	8.2	0.09
19,20	6/4/2009 0:02	2.64	0.005	0.05		0.116	13	66.14	2.1	2.1	1.2	0.01
21,22	6/4/2009 1:02	0.19	0.005	0.05	0.42	0.097	6	84.07	1.6	7.0	5.8	0.04
23,24	6/4/2009 2:22	0.00	0.005	0.05		0.058	17	94.64	1.4	6.9	3.8	0.02

SHA swale		Average Flow	Nitrite-N	Nitrate-N	TKN-N	TP	TSS	Chloride	Zinc	Copper	Lead	Cadmium
Bottles	Sampling Date	(L/s)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
1,2	6/3/2009 20:24	6.11	0.113	0.85	4.48	0.871	138	75.42	138.4	22.3	11.6	0.89
3,4	6/3/2009 20:44	89.65	0.016	0.62		0.332	73	76.06	81.4	15.8	10.9	0.44
5,6	6/3/2009 21:04	83.14	0.022	0.38	2.24	0.258	44	20.48	33.4	8.9	5.2	0.34
7,8	6/3/2009 21:24	28.11	0.021	0.36		0.263	44	10.15	36.3	8.3	5.2	1.14
9,10	6/3/2009 21:44	7.80	0.019	0.28	1.26	0.169	26	14.24	25.9	8.4	4.2	0.13
11,12	6/3/2009 22:04	6.21	0.017	0.25		0.222	25	17.54	35.0	11.4	9.7	0.34
13,14	6/3/2009 22:24	61.84	0.014	0.36	0.84	0.123	43	27.78	40.9	10.0	4.8	0.09
15,16	6/3/2009 22:44	83.60	0.011	0.17		0.135	28	15.24	23.0	7.0	4.9	0.40
17,18	6/3/2009 23:04	27.19	0.007	0.14	1.68	0.135	28	10.5	21.8	7.7	5.3	0.87
19,20	6/4/2009 0:04	6.35	0.009	0.05		0.159	16	12.62	18.7	7.5	5.7	0.13
21,22	6/4/2009 1:04	0.85	0.009	0.09	0.98	0.131	18	18.72	24.5	9.1	5.0	0.10
23,24	6/4/2009 2:24	0.00	0.010	0.05		0.131	42	26.53	26.0	9.6	6.0	0.09

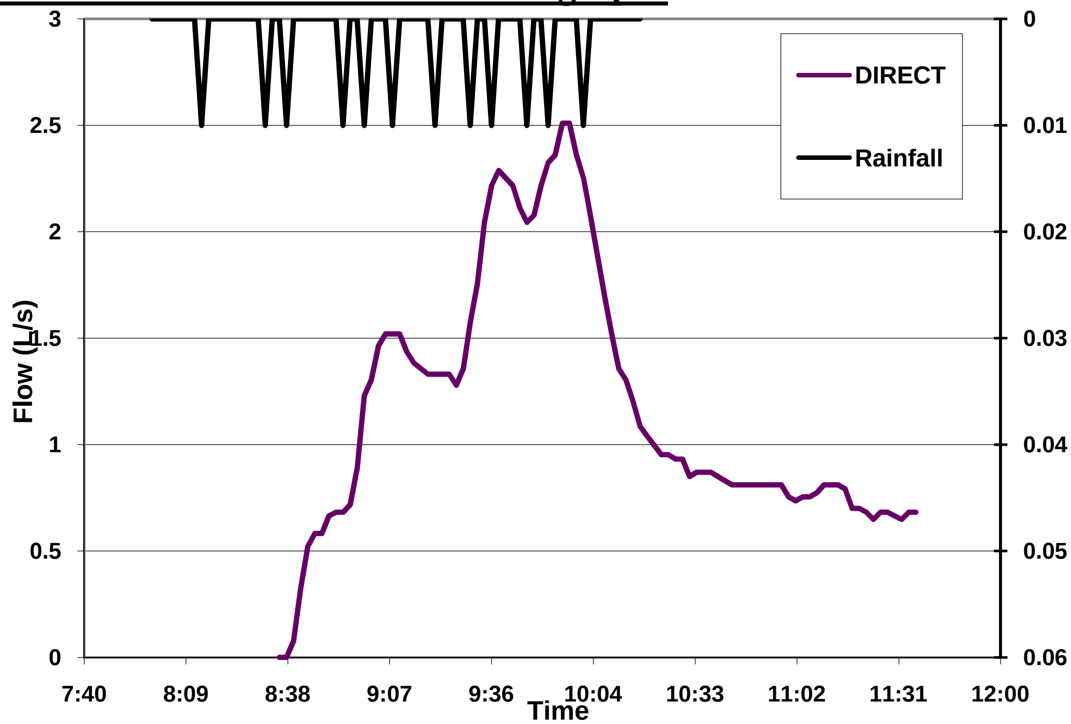
(d) July 1st Storm

Direct		Average Flow	Nitrite-N	Nitrate-N	TKN-N	TP	TSS	Chloride	Zinc	Copper	Lead	Cadmium
Bottles	Sampling Date	(L/s)	Conc (mg/L)	Conc (mg/L)	Conc (mg/L)	Conc (mg/L)	Conc (mg/L)	Conc (mg/L)	Conc (ug/L)	Conc (ug/L)	Conc (ug/L)	Conc (ug/L)
1,2	7/1/2009 21:02	16.43	0.047	0.47	12.04	2.602	396	17.22	1972.0	92.9	44.4	1.78
3,4	7/1/2009 21:22	16.53	0.029	0.45		0.560	127	20.31	1307.0	40.9	9.0	0.84
5,6	7/1/2009 21:42	1.77	0.030	1.23	1.4	0.161	25	45.12	126.7	10.6	5.5	0.17
7,8	7/1/2009 22:02	0.94	0.025	1.64	0.56	0.249	40	55.72	219.9	9.3	6.5	0.16
9,10	7/1/2009 22:22	1.35	0.021	1.37	0.84	0.053	131	48.76	71.3	8.1	6.3	0.17

MDE Swale		Average Flow	Nitrite-N	Nitrate-N	TKN-N	TP	TSS	Chloride	Zinc	Copper	Lead	Cadmium
Bottles	Sampling Date	(L/s)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
1,2	7/1/2009 21:16	2.33	0.0254	0.41	1.68	0.321	94	131.84	52.4	10.1	10.9	0.18
3,4	7/1/2009 21:36	5.66	0.0272	0.38	1.54	0.166	126	135.6	35.4	11.2	12.4	0.18
5,6	7/1/2009 21:56	2.97	0.0309	0.31	1.4	0.197	26	111.26	10.8	6.3	6.1	0.14
7,8	7/1/2009 22:16	0.28	0.0321	0.28	1.26	0.146	19	124.69	1.3	5.5	4.5	0.10
9,10	7/1/2009 22:36	0.00	0.0290	0.22	0.98	0.148	28	138.5	1.0	6.3	3.1	0.14

SHA Swale		Average Flow	Nitrite-N	Nitrate-N	TKN-N	TP	TSS	Chloride	Zinc	Copper	Lead	Cadmium
Bottles	Sampling Date	(L/s)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(ug/L)	(ug/L)	(ug/L)	(ug/L)
1,2	7/1/2009 21:18	3.58	0.0434	1.65	2.24	0.236	19	75.42	24.4	7.2	5.1	0.44
3,4	7/1/2009 21:38	5.10	0.0294	2.13	2.1	0.277	13	76.06	15.8	8.5	5.1	0.15
5,6	7/1/2009 21:58	0.26	0.0641	1.98	2.24	0.344	11	20.48	1.1	8.4	3.4	0.28

Appendix 2. Flow charts with rainfall graphs



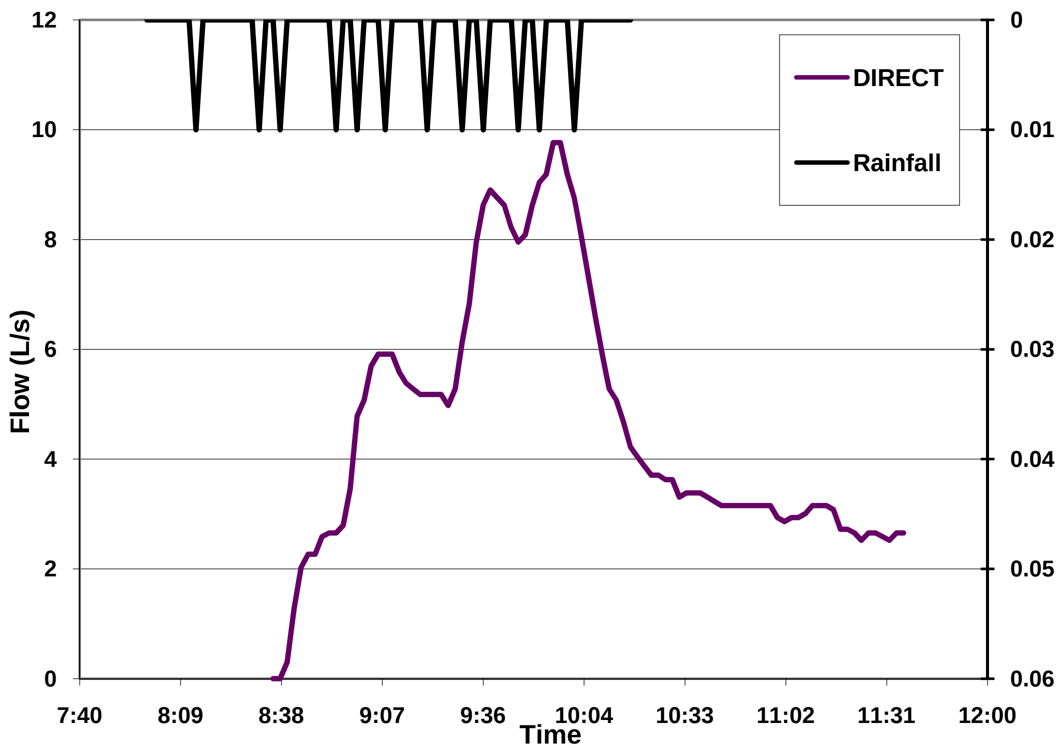
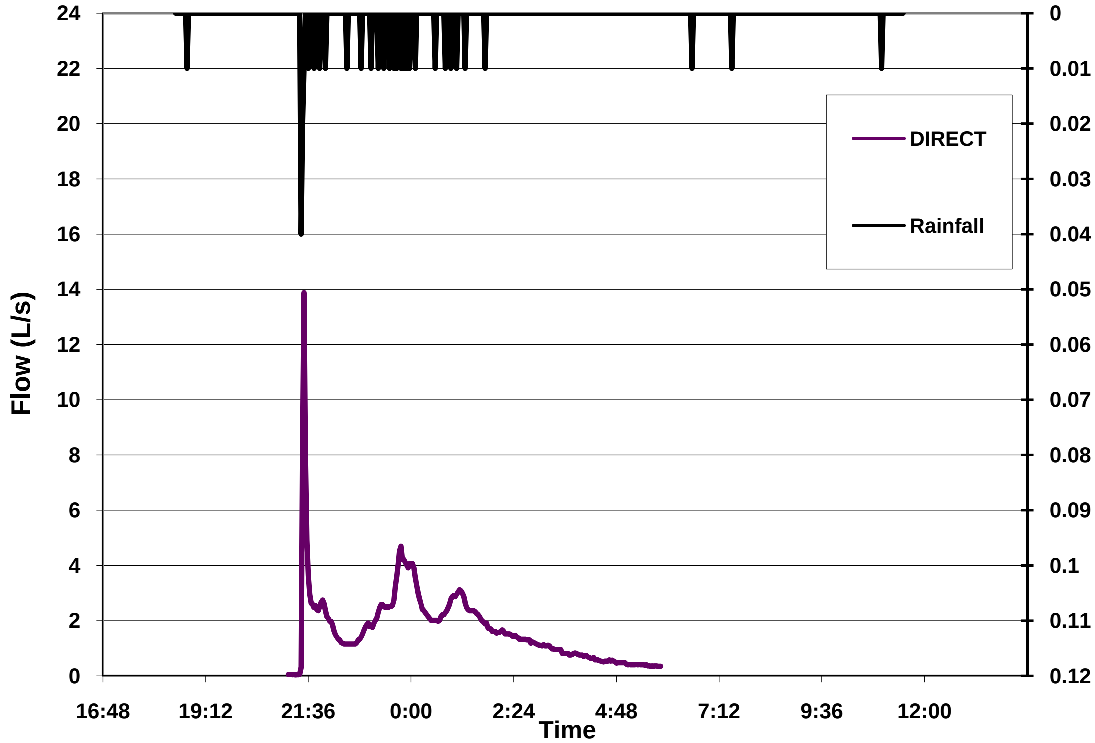


Figure 4. Flow chart with rainfall graph for April 29th storm event; (a) Flow chart, and (b) normalized flow chart (Total Rainfall=0.12 inch).



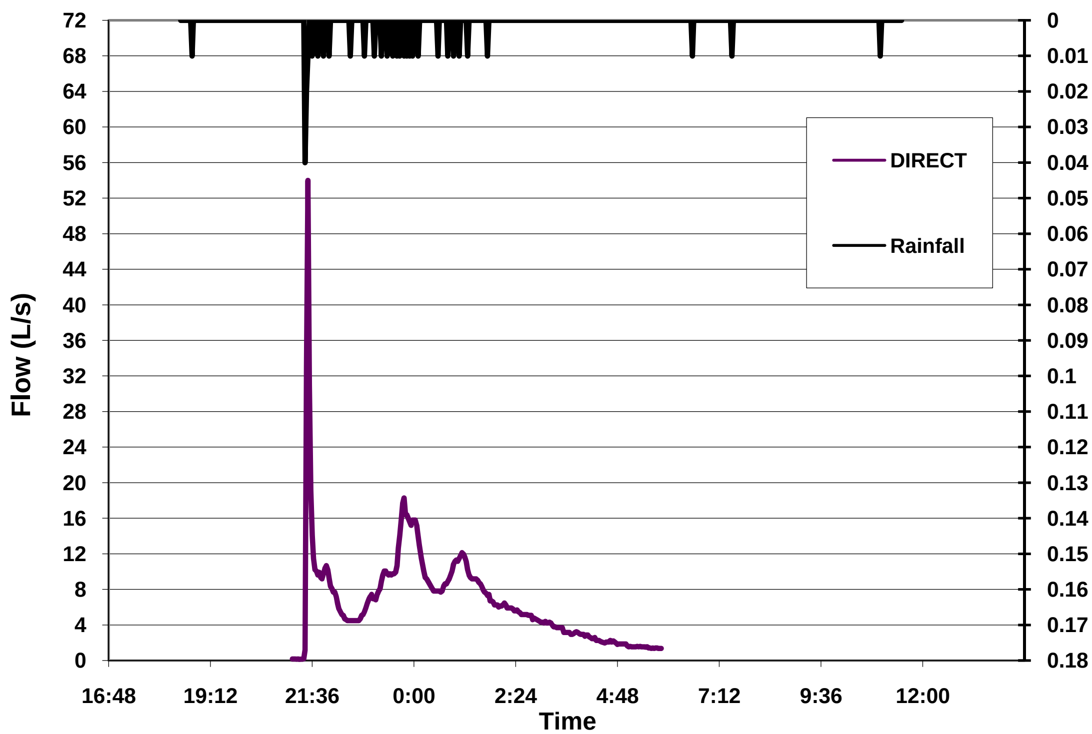


Figure 5. Flow chart with rainfall graph for May 16th storm event; (a) Flow chart, and (b) normalized flow chart (Total Rainfall=0.33 inch).

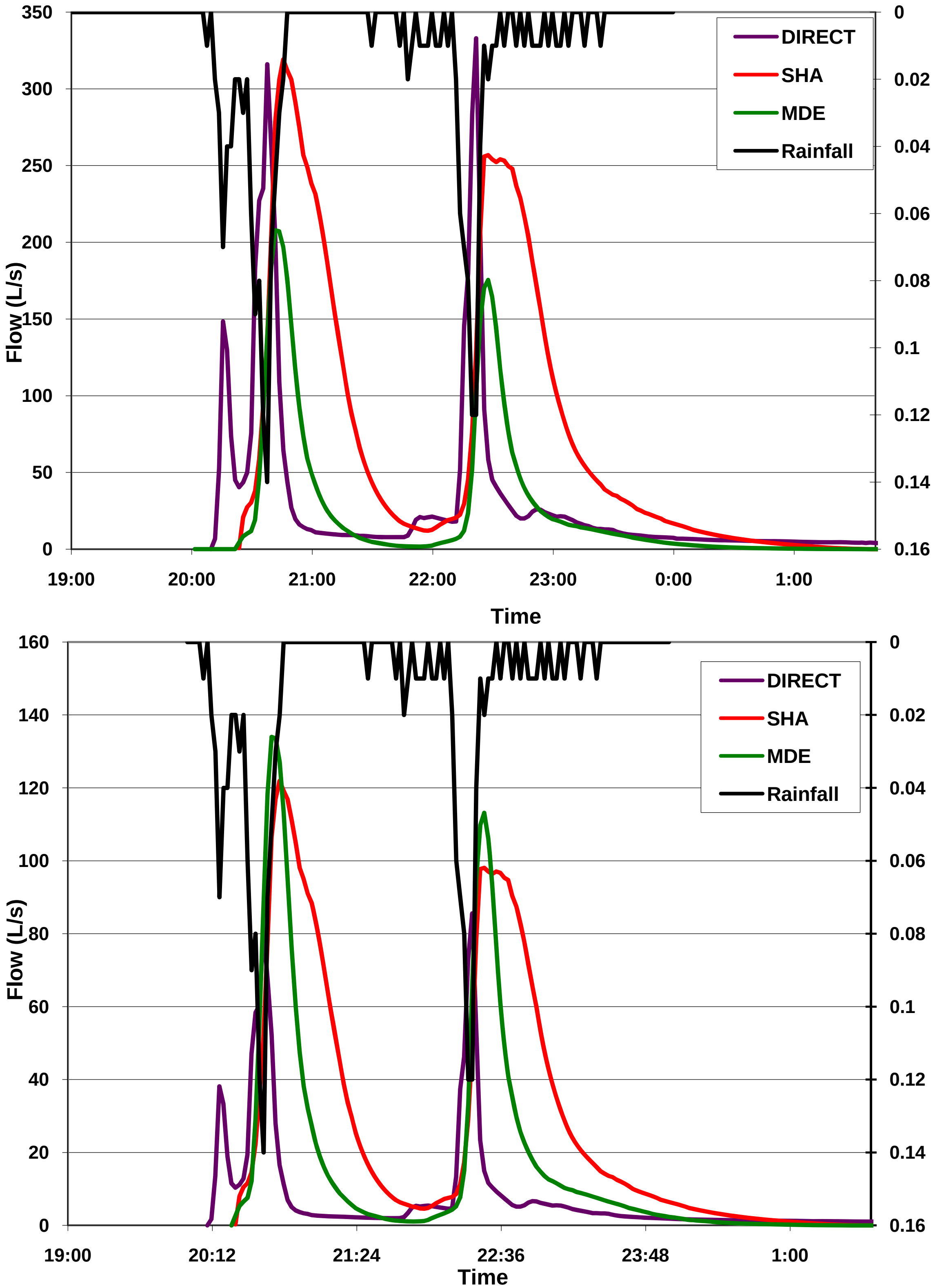


Figure 6. Flow chart with rainfall graph for May 16th storm event; (a) Flow chart, and (b) normalized flow chart (Total Rainfall=1.75 inch).

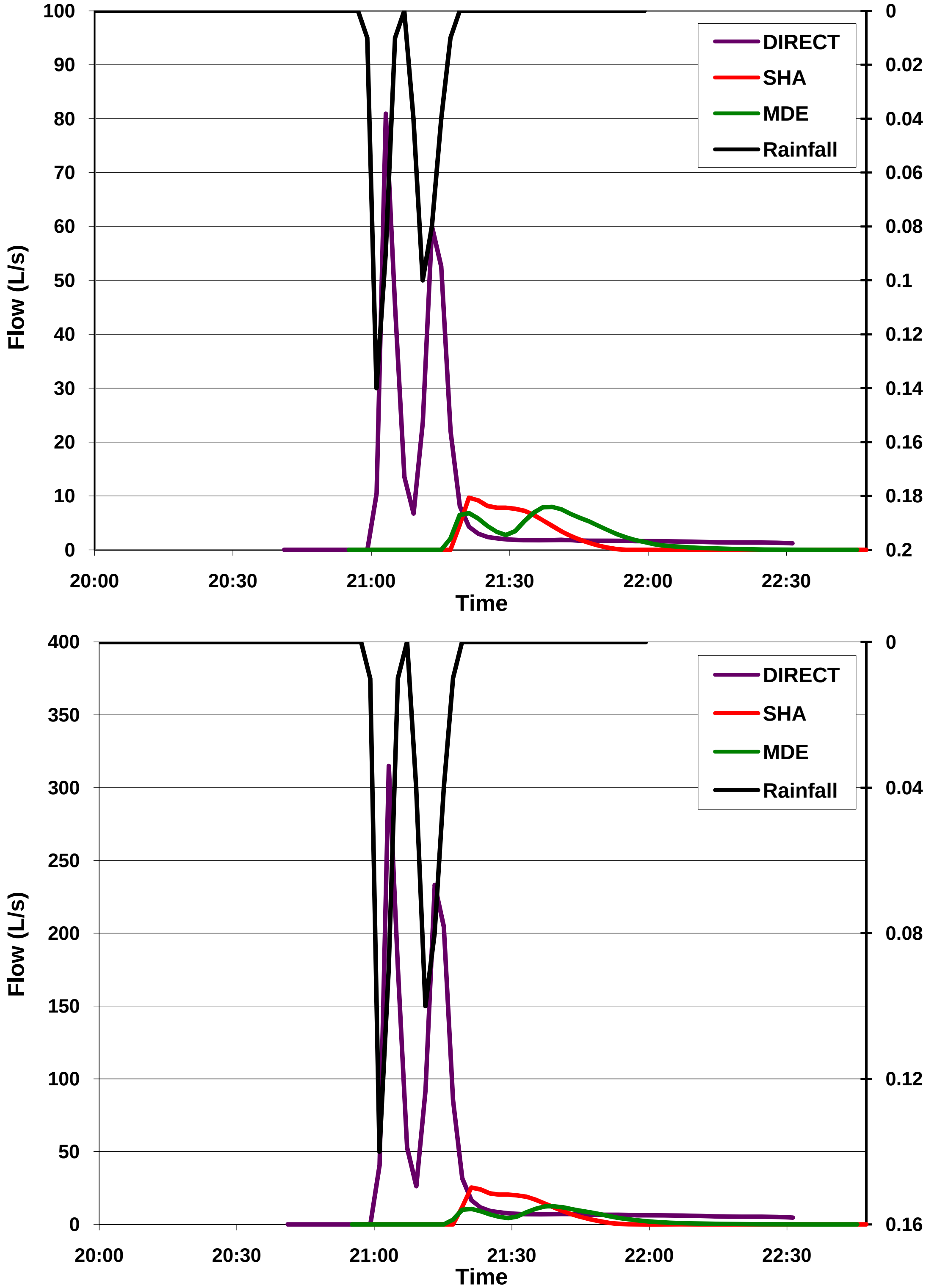


Figure 7. Flow chart with rainfall graph for July 1st storm event; (a) Flow chart, and (b) normalized flow chart (Total Rainfall=0.52 inch).

Appendix 3. Swale Site photos

(a) MDE Swale

(b) SHA Swale

Figure 8. Surface condition of the sampling points of; (a) MDE swale with some bare spots, and (b) SHA swale with well vegetated surface.

(a) MDE Swale

(b) SHA Swale

Figure 9. Check dam for; (a) MDE swale, and (b) SHA swale.

Figure 10. **Pits caused by erosion near direct channel**

APPENDIX D:

Field Evaluation of Wet Infiltration Basin Transitional Performance

Progress Report
August 17, 2009

FIELD EVALUATION OF WET INFILTRATION BASIN TRANSITIONAL PERFORMANCE

Progress Report: Field Evaluation of Wet Infiltration Basin Transitional Performance

Project Duration: December 2008 – July 2009

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FIELD EVALUATION OF WET INFILTRATION BASIN TRANSITIONAL PERFORMANCE

FIELD EVALUATION OF WET INFILTRATION BASIN TRANSITIONAL PERFORMANCE

1.0 Introduction

Land use changes induced by urbanization decrease the perviousness of a watershed, leading to a decrease in infiltration and increase in surface runoff (Dunne and Leopold 1978). Impervious surfaces such as roads, driveways, parking lots, sidewalks, and rooftops accumulate pollutants, including suspended solids, metals, nutrients, pesticides, fecal coliforms, and other contaminants, which are washed off during storm events and eventually delivered to the receiving waters (Barrett *et al.* 1998; Davis *et al.* 2001b; Paul and Meyer 2001). *The National Water Quality Inventory: 2000 Report to Congress* has identified urban runoff as one of the leading sources of water quality impairment in surface waters (USEPA 2005).

Low impact development (LID) techniques have been increasingly adopted to control pollutants in urban stormwater runoff. Strategically located bioretention areas, compact weir outfalls, depressions, grass channels, wetland swales, and specially designed stormwater basins are some of the best management practices (USEPA 2000).

Over the past few decades, a multitude of wet basins have been constructed for stormwater management. An infiltration basin is a shallow impoundment on permeable soil that is designed to capture, temporarily store, and infiltrate stormwater runoff into the ground water over a period of days (Pennsylvania stormwater management manual 2005). In addition to providing water quantity benefit, these BMPs remove pollutants through detention and filtration of runoff (USEPA 1999). Birch *et al.* 2005 studied the efficiency of an infiltration basin, located in Sydney (Australia) in removing pollutants from urban stormwater runoff and reported reduction in total suspended solids (TSS) (50%), total phosphorus (TP) (51%), total Kjeldahl nitrogen (TKN) (65%), trace metals, and fecal coliforms (96%), but increases in oxidized nitrogen species (NO_x) and total nitrogen (TN).

Over the years, inspections have shown that these wet infiltration basins are no longer functioning as originally intended and designed. Infiltration basins can experience reduced infiltrative capacity and will fail if clogging of the soil occurs due to excessive sedimentation (Dechesne *et al.* 2005).

Nonetheless, a separate ecological function may develop in the failed infiltration basins. These practices can gradually transform into a wet pond or wetland-like practice. Functionality of wet ponds and wetlands in removing pollutants from stormwater runoff is well documented (Wu *et al.* 1996; Carleton *et al.* 2000; Birch *et al.* 2004; Brydon *et al.* 2006). Hence, it can be hypothesized that the transformed infiltration basin BMPs will have both water quality and hydrologic management function.

The overall goal for this research is to systematically quantify, through field scale research and monitoring, the performance of a "failed" wet infiltration basin that has naturally transformed into a functional stormwater wet pond or wetland site. Both water quality and flow characteristics will be monitored during storm events and for time periods directly subsequent to storm events. The performance of these systems, as functional stormwater BMPs, will be appropriately documented. Ancillary benefits such as wildlife habitat will also be recorded if possible. If the "failed" BMP is found to provide water quality enhancements, similar sites can be classified as functioning, stormwater management practices.

2.0 Background

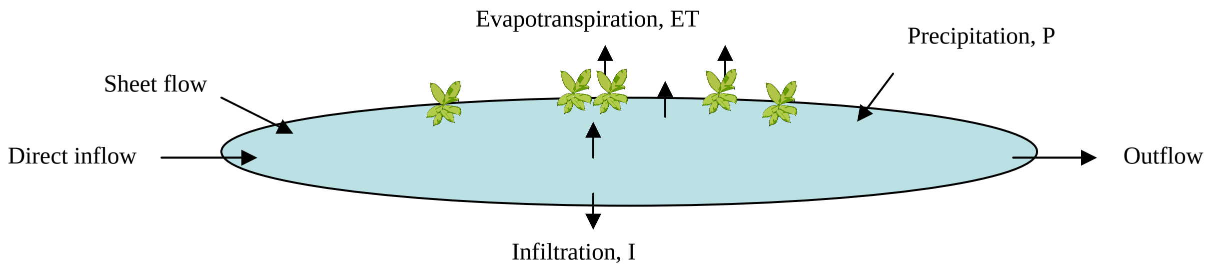
Infiltration basins are structural BMPs that hold a certain volume of runoff that infiltrates into the ground over a period of few hours or days. These BMPs are located on areas with relatively undisturbed (uncompacted), permeable soils, which may or may not be vegetated. Their main purpose is to simply transform the surface water flow into ground water flow and to remove pollutants through mechanisms such as filtration, adsorption and biological conversion as the water percolates through the underlying soil (USEPA 1999). Infiltration basins can be considered to provide 100% surface water pollutant removal, since the inflow runoff completely infiltrates into the soil.

FIELD EVALUATION OF WET INFILTRATION BASIN TRANSITIONAL PERFORMANCE

Infiltration basins are not designed to hold a permanent pool of water. Regular maintenance activities, such as mowing, removing debris and litter, and scraping off the sediment to restore the original infiltration rate, are critical to the performance for these BMPs (Stormwater Center, Stormwater fact sheet). If the basin becomes clogged with sediment, it affects the infiltration rate of the stored runoff into the subsurface. This may cause the impounded water to form a permanent pool and the basin is considered to have "failed". Failure rates of 50% and 100% have been reported in the east coast of the United States (Schueler 2000). Stormwater runoff entering a failed basin may not percolate into the ground, altering the hydrology to form a "wet" basin.

Although a failed infiltration BMP or "wet basin" may not function as originally designed, it may transform into a wet pond or a wetland, which are both known stormwater management practices for flood control and pollutant removal. Wet ponds and wetlands intercept and store runoff, thereby mitigate and delay the inflow peaks, and provide runoff volume reduction (USEPA 1999).

Figure 1 depicts the various components of the hydrological inputs to and outputs from the wet basin system. Water enters the basin via runoff (as concentrated inflow or sheet flow) and precipitation, and is stored in the BMP. Part of the stored runoff may infiltrate into the basin soil. Outflow occurs depending on the volume of runoff received (function of rainfall amount, drainage area, and storage capacity). The presence of vegetation in the basin will cause some loss of water due to evapotranspiration, driven by solar radiation. The basin water storage is determined by the inflows and outflows together with the water loss through evapotranspiration and infiltration.



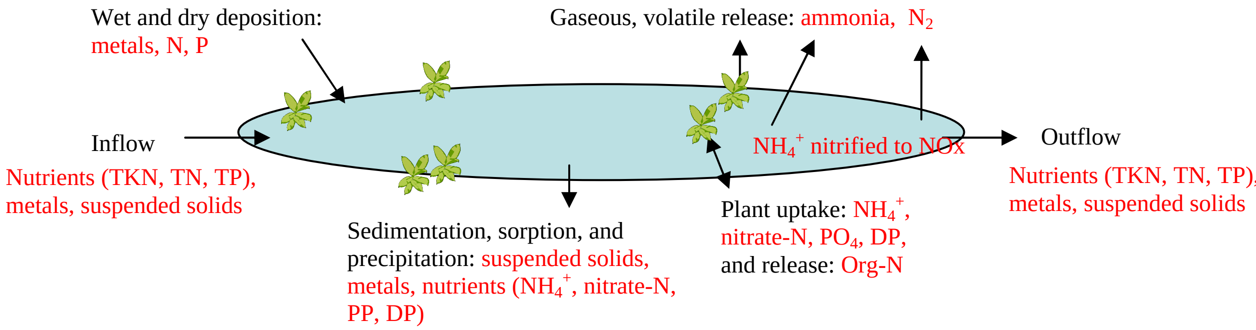
Change in storage = Inflow + (PA) – Outflow – ET – I

A: area of the pond

Figure 1. Schematic of flow balance in a wet (or "failed") infiltration basin.

Considering water quality, both wet ponds and wetlands have been found to be effective in removing pollutants from urban stormwater runoff. Removals in the range of 80-90% for TSS, 21-50% TKN, 22-58% NO_x, 16-48% TN, and 35-65% TP have been reported (Wu *et al.* 1996; Carleton *et al.* 2000; Birch *et al.* 2004; Brydon *et al.* 2006). Removal efficiencies for metals are usually good; Cr (64%), Cu (45-65%), Pb (33%-75%), Zn (31-61%). These BMPs usually show highly variable removal efficiencies of nutrients, nitrogen and phosphorus, generally <50%. Removal of soluble reactive phosphorous (SRP) of -12%, and even -50% has been reported (Comings *et al.* 2000).

As discussed earlier, in wet pond and wetland BMPs, extended residence time provides opportunity for solids to settle and dissolve, and for components to be acted upon either biologically or chemically. All reactions are governed by the presence of aerobic or anaerobic condition in the basin, which creates redox gradients in the soil and water columns. Redox conditions are influenced by hydrological fluctuations, presence of electron acceptors (O_2, NO_3^-, SO_4^{2-}), and transport of oxygen by plants into the root zones (Reddy and D'Angelo 1997). Figure 2 illustrates the transformations that the pollutants (solids, nutrients, and metals) might undergo in a wet pond or wetland-like system.



Total N = TKN (organic and ammonium-N) + NOx –N (nitrate and nitrite)

Org-N —(Ammonification)→ Ammonium – N —(Nitrification)→ NO_2-N → NO_3-N —(Denitrification)→ N_2

Total P = Orthophosphate (PO_4) + Particulate P (PP) + Dissolved P (DP)

Figure 2. Schematic of possible pollutant transformations in a wet basin (or wet pond/wetland).

Suspended solids in road runoff are from pavement wear, vehicles, atmospheric deposition, maintenance activities, and wash off from local soils. The suspended solids in the inflow runoff settle due to gravity. Nutrients (nitrogen and phosphorus) are utilized via complex biogeochemical cycling, which involves many pathways, sinks and sources (Kadlec and Knight 1995). Nitrogen is speciated into various forms: ammonium, nitrate, nitrite, and organic nitrogen. These species are partitioned into particulates, dissolved in water, sorbed, and exist in biomass phases. The nitrogen species transform from organic to inorganic and vice-versa via chemical and biologically-mediated transformations as shown in Figure 2. Ammonium nitrogen (NH_4^+-N) is transformed into oxidized nitrogen forms (NO_x) of nitrite and nitrate by nitrifying bacteria. Some NH_4^+-N is lost through volatilization. Under anaerobic condition, denitrifying bacteria can transform the NO_x species to nitrogen gas. Plants serve as source of organic nitrogen and uptake ammonia and nitrate nitrogen for growth.

Phosphorus is introduced into the system from direct runoff and through atmospheric deposition, which consists of both wet and dry deposition. Phosphorus species are interconverted among its various forms in the wetland-like environment. Soluble reactive phosphorus is taken up by plants or may be sorbed to the sediments. On oxidation, the organic phosphorus becomes soluble. Phosphorus storage occurs in the system via soil building, which can alternate between deposition and wash off.

Metals are introduced in the runoff from vehicles, tires, brake wear, and by atmospheric deposition (Davis *et al.* 2001a). Metals are present in both dissolved and particulate forms in runoff. Heavy metal removal within wetlands has been attributed to various mechanisms including sedimentation, filtration, chemical precipitation and adsorption, microbial interactions, and uptake by vegetation (Walker and Hurl 2002; Yeh 2008).

To summarize, a wet basin, transforming into wet pond- or wetland-like system, would provide peak attenuation through runoff capture and detention, and water quality enhancement by pollutant removal. In addition, it might support varied flora and fauna, thereby providing secondary functionality of habitat for plants and animals.

3.0 Methodology

3.1 Site Description

The Maryland State Highway Administration (SHA) has an inventory of failed infiltration basins in the state. Five BMPs in Howard County were identified as potential study sites and were investigated through field visits to determine their suitability for inclusion in this study. The BMPs were evaluated based on the drainage area, number of inflow and outflow points, accessibility and ease of instrumentation at the inlet and outlet points, and safety at the site. Also, the traffic density and other parameters representative of the State of Maryland were considered during the selection process.

BMP 13348, located along MD-175 eastbound between Dobbin Road and Snowden River Parkway in Columbia, Howard County (Figures 3, 4 and 5), was chosen for the study. The BMP is located within the Maryland SHA right-of-way.

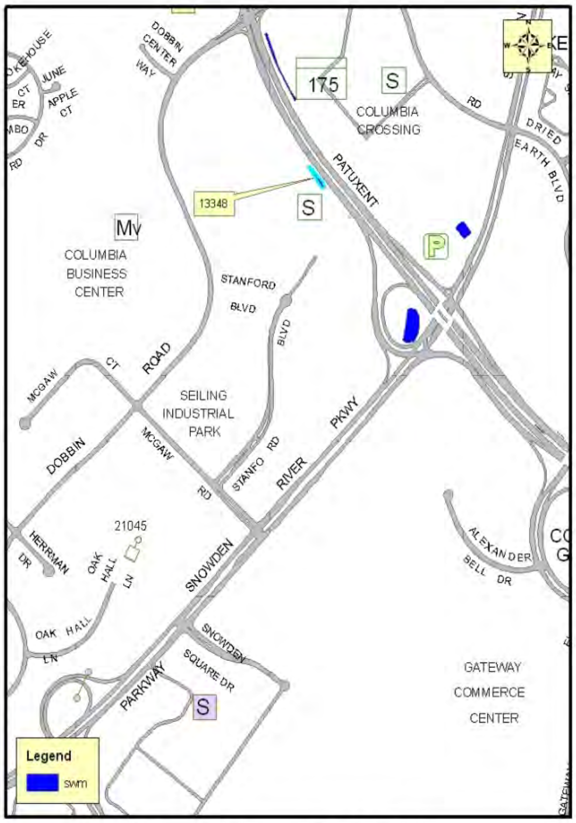


Figure 3. Map location of BMP 13348 along MD-175 east.

Figure 4. BMP 13348 at outflow point, looking east.

Figure 5. BMP 13348 located along MD-175 east. Photo, looking west, shows single concentrated inflow point to the BMP. Some additional flow will occur from sides of the BMP.

The BMP was originally an infiltration basin built in-stream. Currently, the facility is inundated and has been classified as a failed BMP (SHA rating IV). Drainage area to the BMP is 2.23 acres. The BMP has one inflow point and one outflow. The source of inflow is sheet flow from MD-175 and ramp to Snowden River Parkway south, along with culvert and swale flow, and all these flows concentrate within a vegetated swale as the input to the BMP (Figure 5).

3.2 Monitoring

A input/output monitoring approach will be employed to monitor the BMP effectiveness. The BMP will be monitored for flows and water quality samples will be collected after targeted storm events. Flow volume and pollutant mass balances will be performed on the system. A goal of evaluating one event per month is established for an overall goal of 24 events during the 2-year project period. Attempts will be made to monitor a distribution of rainfall events consistent with those expected in Maryland (e.g, many small, short-duration events; fewer high intensity, long duration storms).

3.2.1 Instrumentation and Sampling

Runoff input and output to the BMP will be directed through calibrated weirs. Automated portable samplers (ISCO 6712) will be used for flow monitoring and sample collection at the inlet and the outlet (Figure 6). Each sampler will contain 12 glass bottles and the sampling program will be set to collect 12 samples per event. An example for the sample timing is presented in Table 1, with an emphasis on obtaining more samples in the early part of the precipitation event. The discharge flow is spread over a longer duration due to the expected flow delays through the facility.

The glass bottles will be cleaned and acid washed before placement in the sampler. Filled sample bottles will be sealed, labeled, and then placed in an iced cooler. A single field blank will be collected from a container of deionized water brought from the Environmental Engineering Laboratory, College Park, MD. The field blank will be collected in the same manner as runoff samples, twice rinsing before collecting the sample. Samples will be picked up within 12 hours and transported to the Environmental Engineering Laboratory.

Figure 6. Photo showing sampler and weir installed at the study site.

Table 1. Example sampling times for automated collection during storm events.

	Time	
Sample Number	**Input**	**Output**
1	zero minutes	zero minutes
2	20 minutes	20 minutes
3	40 minutes	40 minutes
4	1 hour	1 hour
5	1 hour, 20 min	1 hour, 20 min
6	1 hour, 40 min	2 hours
7	2 hours	2 hr, 40 min
8	2 hr, 20 min	3 hr, 20 min
9	2 hr, 40 min	4 hr, 20 min
10	3 hr, 40 min	5 hr, 20 min
11	4 hr, 40 min	6 hr, 20 min
12	6 hr	8 hr

In addition to sample collection during storm events, it is proposed to conduct grab sampling during selected dry-weather periods. This baseflow monitoring will provide useful information regarding various physical, chemical, and biological transformations occurring in the BMP. Grab samples shall be collected at multiple locations in the BMP on a biweekly or monthly basis or prior to and following target events as suitable.

Rainfall depth measurements will be done on a 2-minute increment basis using a tipping bucket rain gauge with 0.01 inch sensitivity, installed on top of one of the sampler vaults and connected to the sampler. A probe shall be installed to continuously monitor the water level fluctuations in the facility. Air temperature, relative humidity, solar radiation, wind speed and wind direction data are available from a weather station located about 3 miles from the study site, which can be accessed through the website (<http://www.wunderground.com/cgi-bin/findweather/getForecast?query=21045>). These weather parameters are required to estimation evapotranspiration and hence compute the flow volume balance of the BMP.

3.2.2 Water Quality Parameters

Target pollutants to be monitored include total suspended solids (TSS), nitrate, nitrite, total Kjeldahl nitrogen (TKN), total phosphorus, copper, lead, zinc, and chloride. These pollutants are of the greatest concern in roadway runoff because their concentrations often exceed the limits set by anticipated total maximum daily loads (TMDL) requirements.

3.2.3 Additional monitoring parameters

Parameters such as redox potential, temperature, chlorophyll-*a*, and sediment-pollutant concentrations, which can serve as indicators of the various pollutant transformations occurring in the BMP, will be studied. A tracer study shall be conducted during a dry-weather period and if possible during a rainfall event in order to understand the residence time and mixing characteristics of the facility.

3.3 Analytical Methodology

All pollutant concentrations will be determined based on *Standard Methods* (APHA *et al.* 1995).

3.3.1 Total Suspended Solids (TSS)

TSS is analyzed following Standard Method 2540D (APHA *et al*. 1995). The sample is well mixed and a measured volume of 100 mL is filtered through a pre-weighed standard glass-fiber filter with 47 mm diameter (Pall Corporation). The residue retained on the filter is dried to a constant weight at 105°C for 24 hours, cooled, weighed, and the TSS computed.

3.3.2 Total Phosphorus

Phosphorus analysis is performed following Standard Method 4500-P (APHA *et al*. 1995). Total phosphorus (TP) in the sample is determined by a) conversion of the phosphorus to dissolved orthophosphate by persulfate digestion, and b) colorimetric determination of dissolved orthophosphate by the ascorbic acid method in a spectrophotometer (Shimadzu model UV160U). Fraction of total dissolved phosphorus and dissolved reactive phosphorus are determined in samples filtered through 0.45-µm-pore-diameter membrane following the same principle.

3.3.3 Nitrite

Nitrite analysis follows Standard Method 4500-NO_2^- B (APHA *et al*. 1995). Measured volume of 50 mL of samples filtered through 0.2 µm filters (or 15 mL of the filtrate is diluted to 50 mL) are subject to the colorimetric method. Formation of a reddish purple azo dye on mixing NO_2^- with diazotized sulfanilamide (J. T. Baker) and NED dihydrochloride (Fisher Scientific) is the principle of the method. Photometric measurement of the azo dye is performed at 543 nm. Final concentrations are obtained by applying the appropriate the dilution factor, when applicable.

3.3.4 Total Kjeldahl Nitrogen (TKN)

TKN analysis is performed using Standard Method 4500-NH_3 and 4500-N_{org} Macro-Kjeldahl method (APHA *et al*. 1995) in three steps: a) digestion of 250 mL of sample after addition of 50 mL of digestion reagent, b) distillation of digested sample, after dilution to 300 mL and treatment with 50 mL of sodium hydroxide-sodium thiosulfate ($NaOH$-$Na_2S_2O_3 \cdot 5H_2O$) reagent, into boric acid indicating solution, and (c) titration of distillate with standard 0.02 N H_2SO_4 titrant. Dissolved TKN is determined in samples filtered through 0.2 μm filters following the same procedure.

3.3.5 Nitrate, Chloride, and Sulfate

Nitrate, chloride, and sulfate analyses are performed by ion chromatography. Samples are filtered through 0.2 μm filters. Analysis is performed in a Dionex ion chromatograph (model DX-100) using a 1.3 mM sodium carbonate/1.5 mM sodium bicarbonate eluent at 2.0 mL/min flow rate, and separation occurs in anion columns (AS-4A-SC separator column and an AG-5 guard column). The scale and standard concentrations are selected based on the ions and expected concentration levels; conduction detection level is 10 μS for nitrate, and 30 or 100 μS for chloride.

3.3.6 Total Metal

Metals analysis involves three steps a) digestion of samples by evaporation of 100 mL of sample after addition of 5 mL of trace metal grade concentrated HNO_3. b) filtration and dilution to 100 mL of digested samples and c) analysis of Pb and Cu on the furnace module of a Perkin Elmer Model 5100PC Atomic Absorption Spectrophotometer (AAS) (Standard Method 3110), and Zn on the flame module of the AAS (Standard Method 3111) (APHA *et al*. 1995).

3.3.7 Quality Assurance/Quality Check

Field blanks (or laboratory blanks) are subjected to the same analytical procedure as the samples during each pollutant analysis. Standard calibration curves are validated by checking at least one standard during each pollutant analysis. For ion chromatographic determination of nitrate and chloride concentrations, at least one standard will be run with along with the samples. During metal analysis, standard concentration will be checked after every ten samples. If the error in standard concentration check exceeds ±10%, a new standard calibration curve will be created.

3.4 Data Handling

For each pollutant, the total mass (M) present in each storm event will be calculated as:

$$M = \int_0^{T_d} QCdt \tag{1}$$

where Q is the measured stormwater flow rate and C is the pollutant concentration for each sample during the event. T_d is the event duration. The interval between samples is *dt*. In cases where the concentration of a pollutant is below the laboratory analytical detection limit, a value equal to one-half of the detection limit will be used for calculation and statistical purposes.

The event mean concentration (EMC) is calculated similarly as:

$$EMC = \frac{\int_0^{T_d} CQdt}{\int_0^{T_d} Qdt} \tag{2}$$

The EMC represents the concentration that would result if the entire storm event discharge were collected in a single container. EMC weights discrete concentrations with flow volumes; therefore it is generally used to compare pollutant concentrations among different events.

Pollutant removal efficiency, expressed as a percent removal, may not be an accurate representation of performance of a BMP (Strecker *et al.* 2001). Therefore, in addition to percent pollutant mass removal efficiency, the wet infiltration basin will be evaluated based on effluent pollutant concentrations, statistical characterizations of the inflow and outflow concentrations through probability exceedence distributions with appropriate water quality targets, and total loads in and out of the BMP. Performance will be related to storm characteristics. Also, the distribution of storms studied (intensity, duration) will be compared to expected storm distributions for Maryland.

4.0 Preliminary Study of the BMP

4.1 Sampling and Analyses

Grab samples were collected from the study site on 24 June, 2009. The antecedent event, measuring rainfall depth of 1.77 *in*., occurred on 18 June, 2009. Depth of the ponded water was estimated to be at least 3.5 feet. Emergent plants and algae were visible in the BMP. A total of eight water samples and one sediment sample were collected using a swing sampler. The sampling points were distributed across the BMP in such a manner that they covered the area of the BMP (Figure 7 and 8).

Figure 7. Location of grab sampling points in the BMP, looking west, on 24 June, 2009.

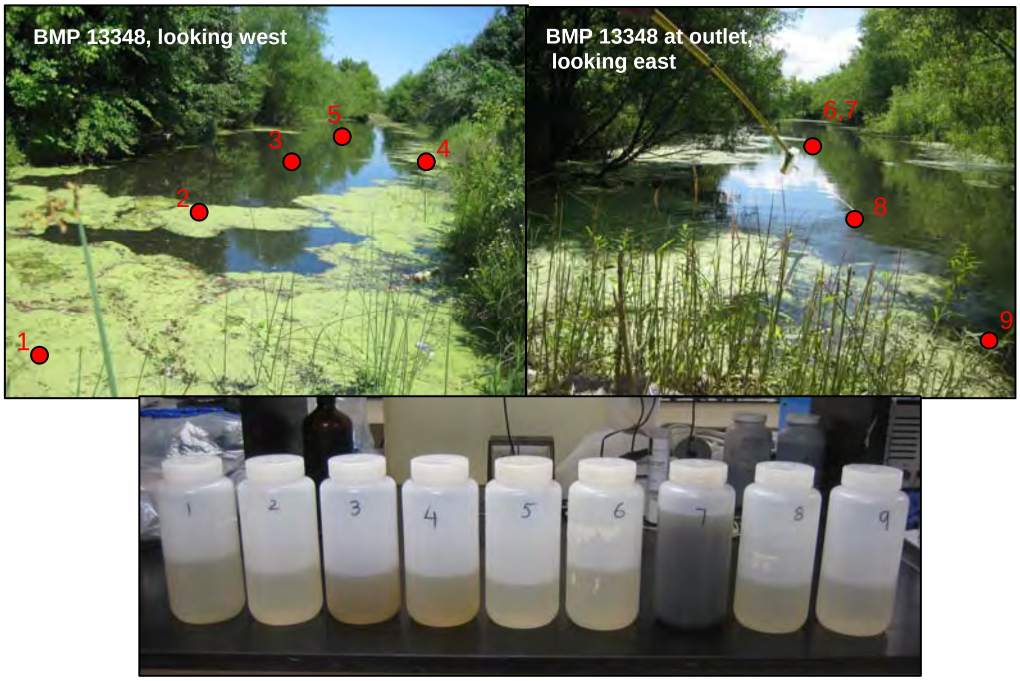


Figure 8. Sampling locations and samples collected during the grab sampling on 24 June, 2009.

At each location, the sampler was carefully lowered into the water all the way to the bottom of the pond, but not touching the bed or disturbing the sediment, so that the sample collected is representative of the depth of the water at that location. Also, algae (or weeds) on the surface were avoided while taking a sample. The sediment sample was collected from the pond bottom at one location (location #7, Figure 8). All samples were collected in acid-washed plastic bottles, sealed, labeled, and were transported in an iced cooler to the Environmental Engineering Laboratory, College Park, MD.

Once transported to the lab, the samples were immediately analyzed for total suspended solids (TSS), turbidity, nitrite, nitrate, and sulfate. A portion of each sample was preserved with concentrated HCl for total phosphorus and metal analyses, and the remaining volume acidified with concentrated H_2SO_4 for TKN analysis. The acidified samples were refrigerated until all analyses were complete. Phosphorus, TKN, and chloride analyses were performed within two days and metal analysis was performed within a week.

The sediment sample was divided into three portions. One portion of the wet sediment was initially dried at 105°C to determine the water content and subsequently dried at 550°C to determine the organic content of the sediment. The second portion of the wet sediment was analyzed for TKN following Standard Methods (APHA *et al*. 1995). The third portion of the sediment was air-dried for two days and then digested by hot nitric acid digestion to a volume of 50 mL. The digested sediment sample was utilized to determine total phosphorus by the ascorbic acid method and total metal by AAS.

4.2 Results and Discussion

The results of the water and sediment sample analyses are summarized in Table 2. The analytical results can be compared with water quality criteria (Li and Davis 2009) given in Table 3. The pHs of the samples were tested in the lab and were found to be neutral. Figure 9 shows that the total suspended solids (TSS) and turbidity follow the same trend. Two of the eight samples show TSS values much higher than the criterion of 25 mg/L. The large variation within samples might be a result of sampling method variation.

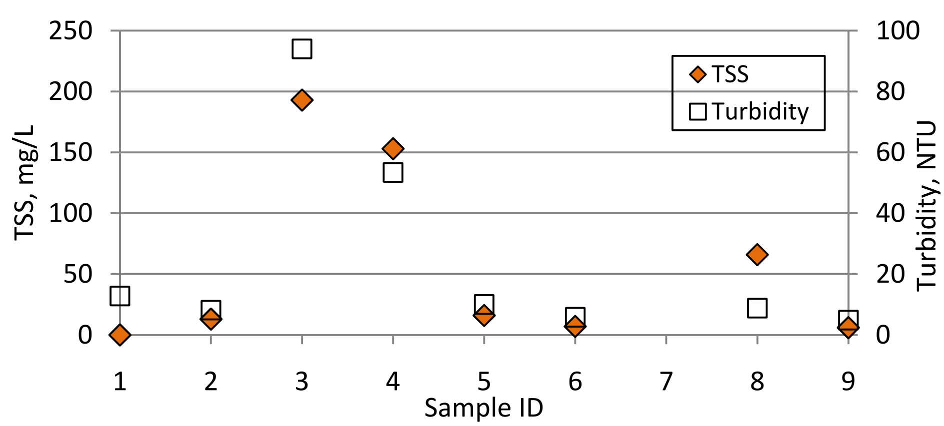


Figure 9. Sample concentrations of TSS and turbidity for June 24, 2009 grab sampling.

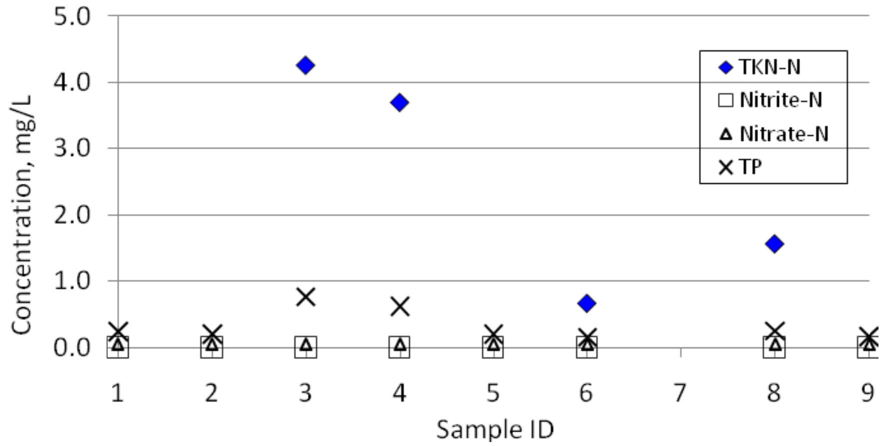


Figure 10. Sample concentrations of nitrogen and phosphorus for June 24, 2009 grab sampling.

Figure 10 shows the concentration of nutrients (phosphorus and nitrogen species) in the samples. Total phosphorus (TP) levels in all eight samples are low. Although greater than the water quality criterion of 0.05 mg/L, the sample TP concentrations are much lower than the expected runoff TP levels of 0.5-20 mg/L (Stagge 2006). Total dissolved and reactive phosphorus are also very low in the samples.

Concentrations of oxidized nitrogen species are also low; the mean concentration of nitrate is 0.05 mg/L and that of nitrite is 0.004 mg/L (Table 2). The mean concentration levels of both nitrate and nitrite in samples are much lower than their respective water quality criteria (Table 3). TKN analysis was performed on four out of the eight water samples. The TKN levels ranged between 0.8 and 4.3 mg/L. Although effort was taken to avoid algae and weeds during sample collection, some of the samples contained plant roots and macroorganisms. TKN in samples would thus include organic nitrogen contributed by plant parts and macroorganisms in addition to the TKN in runoff. Hence, a dissolved TKN analysis was also performed. Bulk concentration of dissolved TKN, determined by mixing two filtered samples collected at two individual locations (#6 and #8, Figure 8), was found to be 0.7 mg/L. Total nitrogen (TN) was determined as the sum of nitrogen species: nitrate, nitrite, and

TKN (TN = NO_3^--N + NO_2^--N + TKN-N) (Table 2). The TN for the four samples ranged between 1 and 4 mg/L.

The chloride level was approximately 13 mg/L in all the samples. This is much lower than the water quality criterion of 250 mg/L. The sulfate concentration in the basin water is also one order magnitude less than the water quality criterion of 250 mg/L (Table 2).

Figure 11 shows the total concentration of the metals lead, copper, and zinc in the basin. It can be observed from the figure that metal concentrations in the water stored in the infiltration basin are all lower than the respective water quality criteria. Thus, Tables 2 and 3 demonstrate that the pollutant concentration levels of the BMP water fall below the water quality criteria for most of the parameters.

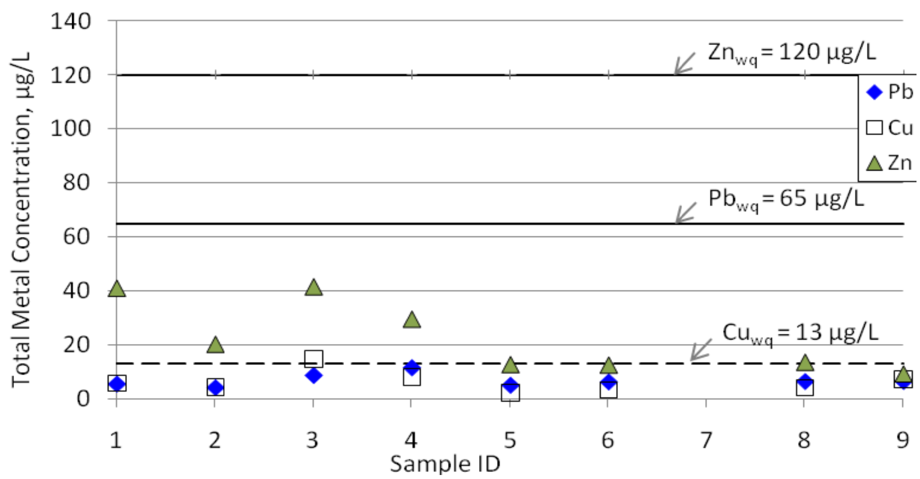


Figure 11. Sample concentrations of total Pb, Cu, and Zn for June 24, 2009 grab sampling. Solid lines represent the water quality criteria for each metal (Subscript "wq" denotes water quality).

Table 2. Summary of sample pollutant concentrations for June 24, 2009 grab sampling.

Sample ID	pH	Turbidity	TSS	Phosphorus			Nitrogen (as N)				Chloride	Sulfate	Total Metal		
				Total	Total Dissolved	Dissolved Reactive	TKN	Nitrite	Nitrate	Total			Pb	Cu	Zn
		NTU	*mg*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*µg/L*	*µg/L*	*µg/L*
1	7.2	13	-	0.07		0.02		0.009	0.05		13	1.8	5	6	41
2		8	13	0.05	0.02			0.006	0.05		13	1.8	< 5[a]	< 5[a]	< 25[a]
3		94	193	0.23		0.01	4.3	0.005	0.05	4.3	13	1.9	9	15	42
4		53	153	0.18	0.05		3.7	0.004	0.05	3.8	13	1.8	12	8	30
5	7.2	10	16	0.05	0.02			0.004	0.05		13	1.8	5	< 5[a]	< 25[a]
6		6	7	0.04			0.7	0.003	0.05	0.7	13	1.9	6	< 5[a]	< 25[a]
8		9	66	0.07			1.6	0.003	0.05	1.6	13	1.7	7	< 5[a]	< 25[a]
9	7.4	5	6	0.04				0.005	0.05		13	1.7	7	< 5[a]	< 25[a]
Sediment				*mg/kg*			*mg/kg*						*mg/kg*	*mg/kg*	*mg/kg*
	-	-	-	1350			12800	-	-	-	-	-	13	54	124

[a]Concentration lower than detection limit

Table 3. Criteria for various water quality parameters (Source: Li and Davis 2009).

Pollutant	TSS (mg/L)	TP (mg/L as P)	Nitrate (mg/L as N)	Nitrite (mg/L as N)	TKN (mg/L as N)	TN (mg/L as N)	Lead (µg/L)	Copper (µg/L)	Zinc (µg/L)	Chloride (mg/L)	Sulfate (mg/L)
Water quality criterion	25[b]	0.05[b]	0.20[b]	1	-	-	65	13	120	250	250

[b]Criteria for excellent water quality in the Potomac River Basin (Davis and McCuen 2005)

The sediment sample collected from the bottom of the basin was analyzed for nutrient and metal concentrations. Loss on ignition examination of the sediment yielded an organic content of about 11%. Total phosphorus concentration associated with the sediment was 1348 mg/kg. The TKN in the sediment was about 12800 mg/kg. Total concentrations of lead, copper, and zinc in the sediment were moderately high.

Water and sediment samples from the basin were collected almost one week after the June 18 rainfall event. It is expected that the pollutants will undergo transformations via physical, chemical, and biological processes. Settleable and suspended solids in the water are removed via sedimentation during the detention period.

Nitrogen species in the runoff exist in particulate and dissolved organic and inorganic (NH_4^+ and NO_3^-) forms. Particulates are removed via settling and dissolved forms are removed via biogeochemical reactions in the soil and water column. The water samples contained very low concentration of nitrate and almost no nitrite. Under aerobic conditions, the organic and ammonium nitrogen species are processed to NO_x via nitrification in the soil and water. Under saturated conditions, soils (sediments) develop reducing (anoxic) conditions, which favors denitrification to convert the NO_x species to N_2 or NH_4^+-N. Additionally, plants assimilate N into their tissues and microbes uptake N for carrying out energy-generating reactions, and hence remove inorganic nitrogen from the system. Also, decomposition of biomass contributes organic nitrogen in the basin. The TN in the sample is mainly due to NH_4^+ -N and organic nitrogen. Therefore, it can be hypothesized that conditions in the wet basin are conducive for nitrification and denitrification to occur. The presence of organic-N in the water may be because the existing conditions limit ammonification of organic-N to NH_4^+ -N.

Total and dissolved phosphorus concentrations in the water samples were low. Phosphorus occurs in dissolved and particulate forms in the runoff. Removal of P from the water column occurs via biotic and abiotic reactions. Particulate-affiliated P is formed by adsorption and precipitation reactions, and subsequently can settle. Biotic phosphorus removal processes include uptake by plants and microbes. Mineralization of plant litter and soil organic-P can release P into the water. Precipitation and dissolution of the nitrogen and phosphorus species are influenced by factors such as redox potential, presence of electron acceptors and donors, pH and temperature of the soil and water.

Total concentration of the metals Pb, Cu, and Zn in the water sample were also low. Metal removal is mainly by binding to sediments and soils, precipitation as insoluble salts, and uptake by plants and bacteria. Mechanisms such as sedimentation and adsorption explain the slightly higher concentrations of nutrients and metals in the sediment of the BMP.

5.0 Summary

Performance of a failed wet infiltration basin in treating stormwater runoff will be evaluated in this research study. As a primary step, grab sampling was conducted at the BMP and the analytical results indicate low concentrations of most of the target water quality parameters. Although the performance of the BMP cannot be interpreted based on this single data set, it is a good commencement of this research. Monitoring the BMP during and subsequent to multiple storm events shall aid the qualitative and quantitative characterization of its treatment potential.

Thus, research and performance information obtained during this study will determine the functionality of these wet infiltration basins in managing roadway runoff. If these basins are found to be providing adequate water quality improvement and controlling the hydrology as they exist, then they need not be treated as "failed" BMPs. As long as their performance is acceptable from a stormwater management perspective, these systems should be permitted to remain.

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APPENDIX E:

Nutrient Removal Optimization of Bioretention Soil Media

Progress Report
August 15, 2009

NUTRIENT REMOVAL OPTIMIZATION OF BIORETENTION SOIL MEDIA

Second Progress Report: Nutrient Removal Optimization of Bioretention Soil Media

REPORT DATE: August 15, 2009

Project Duration: August 2008 – September 2010

Duration Covered: August 2008 – August 2009

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NUTRIENT REMOVAL OPTIMIZATION OF BIORETENTION SOIL MEDIA

NUTRIENT REMOVAL OPTIMIZATION OF BIORETENTION SOIL MEDIA

Executive Summary

Specifications for bioretention soil media (BSM) vary markedly among jurisdictions, even within the state of Maryland. Optimization of media design was investigated for pollutant capture, with a focus on the nutrients phosphorus and nitrogen. A review of current literature and critical analysis of amendment options based on treatment capacity, cost, and local availability led to the selection of aluminum water treatment residual (WTR) as an ideal BSM amendment for phosphorus capture and retention. This, coupled with other measures such as vigorous facility vegetative cover, is hypothesized to be ideal for nutrient removal from stormwater in bioretention facilities. Sorption isotherms were first developed to determine the appropriate BSM amendment content for effective and long term phosphorus capture, found to be approximately 5% WTR by weight. Hardwood bark mulch (HBM) was investigated as an organic matter amendment and shown to potentially increase BSM P capture further. Next steps include vegetated column studies to investigate the system performance of a WTR amended bioretention facility.

1. Introduction

Non-point source pollution continues today to be a challenge that needs addressing by engineers, scientists, and regulators. As development continues and the size of urban conurbations continues to increase, so do the associated impervious areas such as roads, parking lots, and roofs. Urban stormwater runoff from such areas, and the concomitant flux of pollutants to surface water bodies, is an especially pressing issue that requires attention. Low Impact Development (LID) is a development ideology whereby these increases in impervious areas are counterbalanced by providing for on-site green spaces and other areas that attempt to maintain the pre-development hydrology of an area. One LID technology, which also happens to be an EPA Best Management Practice (BMP), that is implemented as a means to reduce runoff pollution discharges is bioretention. Also known as biofiltration or rain gardens, these facilities are effectively shallow depressions filled with sandy media into which runoff is directed. This interception of runoff prevents direct stormwater migration to surface waterways, increases groundwater infiltration, and improves water quality.

Although ongoing research concerning the design and performance of bioretention facilities leads to continued improvement, bioretention remains an immature technology with a number of concerns and issues still to be resolved. Prominent among these is the development of a BSM locally optimized to reach treatment goals, as specifications are inconsistent jurisdictionally. Even within the state of Maryland there is little consensus. Regardless of the media employed, previous research has shown effective removal of suspended solids, oil and grease, and particulate metal species (Davis et al., 2001; Bratieres et al., 2008). While some work has already been undertaken, a means of improving the highly variable removal of dissolved phosphorus and nitrogen species is still necessary. This is because these nutrients lead to the development of eutrophic conditions in surface waters, which is estimated to cost the nation over $2.2 billion every year from recreational and drinking water losses, decreased waterfront property values, and expenses related to threatened/endangered species habitat recovery (Dodds et al., 2009).

2. Literature Review

2.1. Hydrologic Benefits

Bioretention as a technology efficiently mitigates peak flows, leading to reductions in stream erosion. Maintaining or returning a site's hydrology to a predevelopment state is one of the technology's major advantages. A high hydraulic conductivity is integral to this

(Hsieh and Davis, 2005). Even in the harsh environment of the field, bioretention has shown marked improvement of site hydrology (Davis, 2008).

2.2. Particulate capture

Excellent removal of particulate pollutants has also been shown, including total suspended solids (TSS); metals such as Pb, Cu, Zn, and Cd; and particulate phosphorus. TSS has been shown to be removed predominantly in the surface mulch layer and upper soil profile of bioretention cells (Li and Davis, 2008a; 2008b). Metals may be found in both particulate and dissolved forms. When particulate, they are stopped via filtration mechanisms of the soil and mulch much the same as TSS. In dissolved form, they will bind to organic material such as the mulch top dressing and organics within the bioretention soil (Davis et al., 2001). In fact, work has shown that effective removal of particulate contaminants takes place in approximately the top 20 cm (8 in) of the bioretention media (Li and Davis, 2008a; 2008b). In this same research, Li and Davis (2008a) recommend a media depth of only 20 to 40 cm (8 to 16 in) to effectively remove particulate-associated pollutants.

2.3. Phosphorus

The Metropolitan Washington Council of Governments (MWCOG) reported ranges for total P and N of 0.10 – 0.66 mg/L and 0.25 – 1.4 mg/L, respectively, in urban stormwater runoff in the Washington area (MWCOG, 1983). The U.S. EPA Nationwide Urban Runoff Program reported that stormwater, on average, contains 1.5 mg/L total Kjeldahl nitrogen (TKN) and 0.68 mg/L oxidized nitrogen species (NOx). They also reported an average of 0.33 mg/L phosphorus (TP), of which 0.12 mg/L is soluble (SP). This equates to 64% of phosphorus in stormwater being in particulate form (US EPA, 1983).

In particulate form, P is predominantly captured through the filtration mechanism of the BSM. However, dissolved P often remains not just uncaptured, but may be produced through the degradation of organic material associated with the bioretention media (Hsieh et al., 2007a; Bratieres et al., 2008). This degradation leads to inconsistent removals of nutrients like P and nitrogen (N). Sufficient vegetative coverage and selection of appropriate plant species has been found to greatly control P mobility through uptake. Significant differences in nutrient uptake have been found among plant species, making selection of utmost importance (Lucas and Greenway, 2007; Read et al., 2008). Amendments have also been investigated to promote P capture within facilities. Zhang et al. (2008) investigated the incorporation of coal combustion fly ash for P immobilization, with encouraging results.

2.3.1. Mineral interactions

P removal is a complicated challenge however, as there is conflicting evidence of which factors promote and diminish P retention is soils. The primary P removal mechanisms involve interactions with iron (Fe), aluminum (Al), calcium (Ca), and to a lesser extent magnesium (Mg). Immobilization in calcareous environments is primarily through reactions with Ca and Ca-containing compounds. Primary mechanisms in acidic environments are sorption to Fe and Al (hydr)oxides (Ann et al., 2000; Zhao et al., 2007). Work has shown that adsorption to Fe and Al (hydr)oxides is optimal at pH 5.6 to 7.7, while for Ca phosphate precipitation it is pH 6 to 8.5 (Ann et al., 2000).

2.3.2. Organic matter interactions

2.3.2.1. Sorption site competition

Organic matter has been shown to possibly compete with P for sorption sites on Fe, Al, and Ca compounds, and in this way may reduce P capture in bioretention. Borggaard et al. (2005) observed that P will outcompete organic matter for adsorption sites of $Al(OH)_3$ (as well as iron (oxyhydr)oxides) if provided with sufficient contact time. Unfortunately, sufficient time was show to be at least 2 days (Borggaard et al., 2005), well beyond the time permitted in bioretention systems. Because of this, mixing order is important. P will control the sorption sites when in contact without organic matter, while if organic matter and the sorption sites are associated first, it will take time for P to exchange with the organic matter and become sorbed to the sites (Borggaard et al., 2005).

Other research has shown increased rather than competitive P sorption in organic matter rich soils (Kang et al., 2009). This has been attributed to the formation of metal-organic matter complexes in the soil that can provide sites for increased P retention. Obviously these results are contradictory with those above, and the matter is still under investigation. Ultimately, evidence suggests that if sorption sites are present in sufficient abundance, there will be no competition and both organic material and P will sorb (Guan et al., 2006).

A statistical path analysis was conducted on soils from North Carolina by Kang et al. (2009). The interactions between phosphorus adsorption in the soils and various soil parameters, including oxalate-extractable aluminum and organic matter contents, were analyzed. Results suggest that there is a direct effect of oxalate-extractable aluminum content on P adsorption, and an indirect effect of organic matter content on P adsorption via aluminum content. This suggests there is some manner of interaction between oxalate-extractable aluminum and soil organic matter, resulting in soil P adsorption. Furthermore, their findings show a steep positive correlation between increasing organic matter content and P adsorption, up to a certain point deemed the change point. This change point was observed at approximately 5% organic matter content. The correlation between P adsorption and organic matter had a slope one order of magnitude lower when soil organic matter content was above this change point (greater than 5%), suggesting that beyond this change point the benefit of increased P adsorption provided by increasing organic matter content is greatly reduced.

2.3.2.2. Organophosphorus release

Organic matter itself also often contains P, and its breakdown within and on the bioretention media is implicated through increases in leaching of the soluble organic fraction of P (Hsieh et al., 2007a; Bratieres et al., 2008). This occurs as soil microorganisms, plant roots, and mycorrhizae release phosphohydrolase, enzymes that mobilize P to allow for uptake by the organism. Significant release of organic P (P_o) from soil organic matter has been observed to only occur when inorganic P (P_i), such as the predominant orthophosphate [PO_4(-III)] found in runoff, is limited in supply (McGill and Cole, 1981). A very coarse means of determining whether P_o will mineralize or become immobilized is through the ratio of organic carbon (org C) to P_o. When org C:$P_o \leq 200$, mineralization will occur; when org C:$P_o \geq 300$, it will not (Dalal, 1977). While this is an imprecise measure, it does allow some quantification for the potential of P_o release from mineralized organic matter in soil and bioretention media.

2.3.2.3. Soil drying

Soil drying is another important component of this P mobilization. Even minor drying of soils has been shown to dramatically increase the amount of soluble P, through crystallization of compounds, soil aggregate breakdown, and disruption of clay organic matter coatings (Worsfold et al. 2005; Styles and Coxon, 2006). However, organic matter may play an important role in P retention as well through retention of soil moisture. This prevents soil drying and the concomitant crystallization of P sorbing metal compounds. Amorphous compounds have a vastly superior ability to bind phosphorus compared to crystallized, attributed to their appreciably larger surface area (Darke and Walbridge, 2000). Therefore organic matter such as that found within bioretention media and as the surface mulch layer may ultimately lead to greater P retention through increased sorption capacity, brought about by maintaining P complexing compounds in an amorphous state. It also will provide a carbon source in the event of saturated conditions and the occurrence of biological denitrification reactions in the subsurface. A graphical representation of P interactions in a bioretention cell is presented in Figure 1.

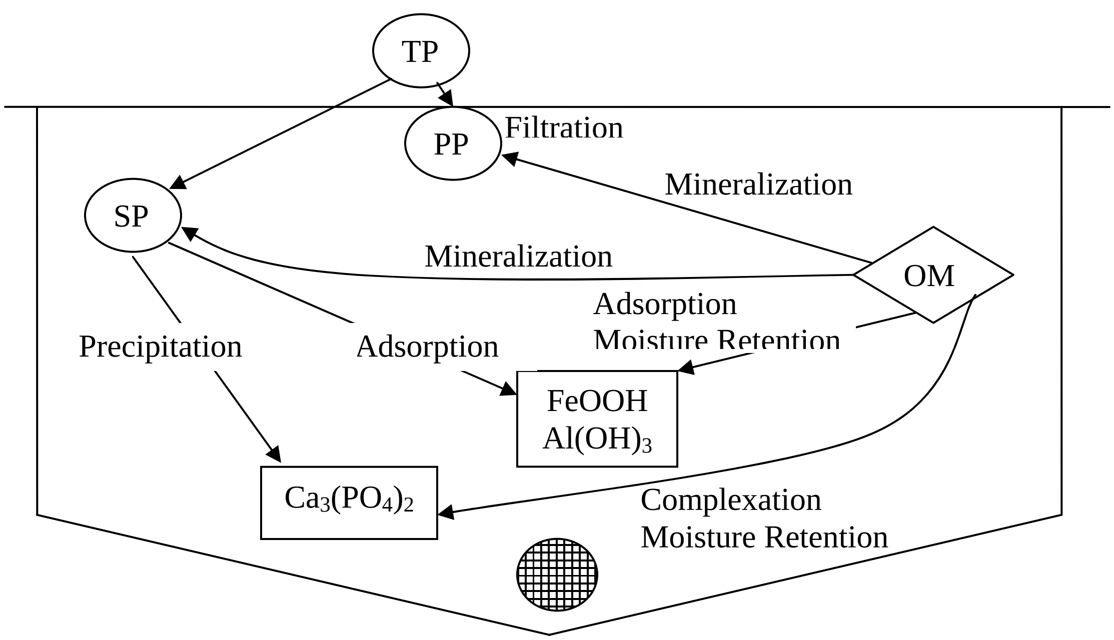

Figure 1. Phosphorus interactions in a bioretention cell. TP – total phosphorus, SP – soluble phosphorus, PP – particulate phosphorus, OM – organic matter. $Ca_3(PO_4)_2$, FeOOH, and $Al(OH)_3$ exemplify calcium phosphates, iron (oxyhydr)oxides, and aluminum (hydr)oxides, respectively.

2.4. Organic Matter Characterization

Organic matter amendment materials were chosen for investigation after comparison of the C:N:P ratios of their constituents from the relevant literature (Byard et al., 1996; Yarie and Van Cleve, 1996; Antikainen et al., 2004; Beauchamp et al., 2006; Sardans et al., 2008). These components include bark, wood, sawdust, leaves, leaf litter, and leaf mulch compost. The C:N:P ratios vary greatly among components and depend on the specific species of plants or trees from which the materials were made, as well as the conditions under which they were grown. However, in general, wood based organics such as bark have a higher C:N:P ratio than that of many other organic materials as they contain less N and P per unit of C.

2.5. Nitrogen

Like particulate P, organic nitrogen (Org-N) and ammonium (NH_4^+) are often effectively captured through filtration and sorption to negatively charged soil particles. However, these compounds are degraded to the NOx species nitrite (NO_2^-) and nitrate (NO_3^-), which are soluble and readily leach through soils (Dietz and Clausen, 2005; Hsieh et al., 2007b; Bratieres et al., 2008). Prevention of NOx leaching has been observed through vegetative coverage (Bratieres et al., 2008; Read et al., 2008), as well as the establishment of anoxic zones in the media to promote denitrification of NOx to nitrogen gas (Kim et al., 2003; Hunt et al., 2006).

3. Research Objectives

This study purports that greatly improved P retention without compromising media hydraulic conductivity may be induced in BSM by augmentation with aluminum-based water treatment residual (WTR). WTR is a byproduct of drinking water treatment when alum (aluminum sulfate) is added to the water as a coagulant. Once in solution, the sulfate and aluminum dissociate and the aluminum forms aluminum (hydr)oxide. Suspended material in solution is also made to form flocs from this alum addition, which precipitate from solution. This settled material, upon removal from the settling tank and dewatering, is classified as WTR. It has a very high potential for P adsorption because of its large component of amorphous aluminum (hydr)oxide.

It is hypothesized that aluminum WTR will perform ideally in the relatively acidic soil environment of the east coast of the United States. Many other materials were reviewed as potential BSM amendments, including coal combustion fly ash and steel slag, but were decided to be inappropriate because they operate mainly through Ca-P complexation which performs optimally in an alkaline environment. Also, iron based WTR were reviewed, but rejected because of the scarcity of use in the Baltimore-Washington corridor, as well as the potential for iron to release all adsorbed P upon inducement of subsurface reducing conditions. Additionally, the affects of pH on aluminum WTR adsorption will be briefly investigated, as evidence suggests the adsorption capacity of aluminum hydroxide will increase with decreasing pH (Lijklema, 1980; Ann et al., 2000; Zhao et al., 2007).

As explained above, organic matter imparts qualities both beneficial and detrimental to P retention. An organic matter with high carbon content and relatively small amounts of N and P is hypothesized to be ideal for moisture retention without ultimately leading to increased nutrient leaching. A small but carefully selected preliminary group of organic materials including shredded hardwood bark and leaf compost will be briefly investigated as to their ability to retain soil moisture and the effect of their addition on P adsorption. Bark mulch is expected to minimally affect P adsorption due to its high C:N:P ratio, and provide increased soil water retention capacity by maintaining the aluminum (hydr)oxide in the WTR in an amorphous, high-P adsorbing state. Leaf compost, conversely, is expected to have a very low C:N:P ratio, ultimately causing reduced phosphorus adsorption. It was chosen for investigation to provide a negative control for the effects of organic matter amendments on the phosphorus adsorption capacity of BSM.

It is proposed that the benefits of greater P adsorption from amorphous aluminum hydroxide will outperform any possible loss in adsorption capacity from addition of organic matter. In the end, combining this amendment with an increased nitrogen removal measure such as carefully selected vigorous plant coverage and/or an anoxic denitrification sump is theorized to lead to dramatically increased removal efficiency in the system without sacrificing hydrologic benefits such as increased infiltration.

This project will first develop phosphorus sorption isotherms to determine the optimal WTR content as a media amendment for phosphorus capture. Equilibrium with P at low concentration in solution will be focused on especially, because of the low P concentrations typically found in urban stormwater. This differs from the preponderance of published research in the field of stormwater P capture using soil amendments, which primarily are focused on situations in agriculture subject to much higher P concentrations. The effects of organic matter on phosphorus adsorption will then be investigated. This will include both its measure as a competitor for $Al(OH)_3$ adsorption sites, as well as increased capture potential through moisture retention when undergoing wetting/drying cycles. Lastly, vegetated column experiments will be conducted to evaluate nutrient removal in pilot scale bioretention systems using WTR as an amendment

4. Methodology

P batch studies for determination of adsorption isotherms were initially conducted to determine adsorption of various BSM mixtures, which allowed prediction of adsorption behavior under various conditions as well as to ultimately determine the best performing BSM at this stage. The most promising mixtures investigated were then used in small column studies receiving a P solution to determine their adsorption behavior under flow conditions. Mixture performance could be verified with these studies and adequate hydraulic conductivity of the media ensured. Performance under wet/dry cycles will also be investigated at this stage in an attempt to simulate actual bioretention conditions. Larger, vegetated columns will then be investigated with the best performing mixtures. These larger columns will receive a complete suite of pollutants, including orthophosphate, ammonium, nitrogen oxides, and organic nitrogen to determine BSM performance for pollutant removal. Plant survival will be observed to determine possible toxicity or other negative effects of WTR addition. Possible leaching of free aluminum will also be investigated, as this metal is toxic to many aquatic organisms. All mixtures and BSM components are subjected to acid ammonium oxalate extraction for oxalate-extractable P, Al, and Fe content. These data are compiled for use as a measure to determine P adsorption potential, and conversely leachability risk, for BSM mixtures.

4.1. Bioretention Soil Media and Phosphorus Adsorption Isotherm Determination

BSM was obtained pre-mixed from a local landscape supplier, passed through a 2-mm sieve, and sent to the University of Delaware Soil Testing Program for particle size analysis. The media contained 77% sand, 15% silt, and 8% clay, and was classified as a sandy loam per USDA soil texture classification. The media was stored in water tight containers, and before use was air dried for at least 1 week.

Aluminum based WTR was secured from the Rockville Drinking Water Treatment Plant in Potomac, MD. Until use it was stored in water tight covered containers to retain moisture. The work of Yang et al. (2008) showed conclusively that the phosphorus adsorption capacity of aluminum WTR stored in such containers is not affected by ageing for at least 18 months, and so the material used is expected to be representative of fresh aluminum WTR. Prior to use as a soil amendment, the WTR was crushed by hand, sieved < 2 mm, and then air dried for at least 1 week. Mixtures were prepared by weighing soil and WTR and then placing in sealed bags and homogenized through vigorous shaking.

P isotherms were determined for unamended BSM, as well as that amended with 2, 4, and 10% aluminum WTR on a per weight, air dried basis (1.2, 2.4, and 6.0% WTR on a per weight, oven dried basis, respectively), using a modified method based on that reported by Nair et al. (1984). Summarily, NaH_2PO_4 was used to make 0.3, 0.9, 3.0, and 9.0 mg/L P solutions with a 0.01 M KCl background electrolyte concentration. Isotherms were prepared as follows: 1.8 g of media mixture was weighed out and placed in each of 5 centrifuge tubes of 50 mL volume. To these was added 45 mL P solution, for a media:solution ratio of 1:25 (w/v). A sixth centrifuge tube containing no media, but 45 mL of appropriate P solution was carried through all procedures with the samples as a blank. Each of the four WTR amendment treatments had phosphorus solution addition at 0.3, 0.9, and 3.0 mgP/L strength. In addition, the 10% WTR treatment underwent addition of the 9.0 mg/L phosphorus solution, and these data were included in the isotherm. Due to the high adsorption capacity of the mixture, this was necessary to extend the isotherm and provide for comparison of all four treatments.

For each treatment and P solution addition, investigation was then undertaken to observe the effects of varying pH on P adsorption. Three samples were acidified to approximately 4.00, 4.25, and 4.50 pH, respectively, using 0.05 – 0.2 mL 0.1 M HCl; to one sample was added 0.05 – 0.1 mL 0.1 M NaOH to produce a pH of approximately 7.5 to 8.5. The final sample as well as the blank underwent no pH adjustment. Samples were than shaken on an end-over-end shaker for 24 hours, after which they were centrifuged at 2000 rpm for 13 minutes and the supernatant decanted and filtered through a 0.22 μm membrane filter. Final pH was measured and then the samples were analyzed by the ascorbic acid molybdenum blue method as presented in Standard Methods (APHA, 1992). A 5 cm pathlength cuvette was employed to provide a detection limit of 0.01 mg/L P.

4.2. Low-fines BSM

Influence of clay content on P adsorption was undertaken by the addition of sand to the BSM to reduce the fines (silt and clay) content. Concurrently, this also provides an estimation of performance of media mixtures of a different textural class. The BSM was amended with angular, white quartz sand to produce a textural profile of 85% sand, 10% silt, and 5% clay; rated as a loamy sand per the USDA soil textural classification. Henceforth, this media mixture is referred to as low-fines bioretention soil media (LFBSM)

Phosphorus adsorption isotherms were also undertaken, performed as per the method outlined in section 4.1. Again, each LFBSM treatment underwent the addition of 0.3, 0.9, and 3.0 mg P/L phosphorus solution. A 9.0 mg P/L solution was not employed in isotherm determination as it was not necessary. LFBSM WTR treatments, in contrast to those of the

BSM, consisted of 0 (unamended), 3, 6, and 10% WTR on a per weight, air dried basis (0, 1.8, 3.5, and 6.0% WTR on a per weight, oven dried basis, respectively).

4.3. Organic Matter Amended BSM

The WTR amended BSM was further amended with organic material to investigate the effects of such matter on phosphorus adsorption capacity. The chosen materials were hardwood bark mulch (HBM) and leaf-and-yard-waste-based compost (LC). The HBM was purchased from a local landscaping supply company in the Washington, DC area, and the LC was obtained from the College Park, MD Department of Public Works and is their screened Smartleaf® Compost.

The chosen organic matter amendments provided increased soil organic matter to the BSM, as did the WTR. HBM was 84% OM, LC was 47% OM, and WTR was 40% OM, as measured by loss on ignition (LOI) at 550°C (Table 1). The high organic matter content of the WTR is somewhat misleading, as this is not representative of organic matter typical of surface waters. It is believed to have two causes: additionally released water from hydrous oxides upon ignition (Elliott et al., 2002); and the use of an organic polymer (Praestol N3100LTR; Ashland, Inc.) in the drinking water coagulation process (Vern Simmons, Rockville Drinking Water Treatment Plant, personal communication).

Because of the high measured organic matter content of the WTR, noticeable increases in BSM organic matter content were observed with increasing WTR content. Therefore, it was decided to amend all WTR treatments with an equal amount (mass) of organic material (either mulch or compost). In accordance with the findings of Kang et al. (2009), it was decided to amend the 2% WTR treatment with organic material to produce a

5% organic matter content. The organic amendments were mechanically shredded and sieved < 2 mm, then added at field moisture (48% and 58% water content for HBM and LC, respectively) to air dried WTR amended BSM at a ratio of 1:16.1 (w/w) HBM:WTR amended BSM and 1:7.7 (w/w) LC:WTR amended BSM. Organic amendments were added at field moisture vis-à-vis air dried weight to prevent uncharacteristic P leaching that would result upon rewetting. The addition of the organic amendments to WTR amended BSM did result in a net reduction in WTR content, but this was minimal (≤ 0.5% net change in WTR content of the mixtures on an oven dry weight basis). Table 1 details the proportions of all constituents in the mixtures investigated in this study.

Phosphorus adsorption isotherms were generated, utilizing the method outlined in section 4.1. The effects of HBM addition on P adsorption were investigated with unamended, 2% WTR, and 4% WTR BSM. The investigation of LC involved unamended and 4% WTR BSM. Additionally, 4% WTR BSM was amended with an increased mass of LC to further investigate the negative effects of LC on P adsorption. This increased LC addition occurred at approximately 2.5 times the initial mass, having a ratio of addition of 1:2.8 (w/w) LC:WTR amended BSM.

Table 1. Aluminum based water treatment residual (WTR) and organic matter (OM) content of all investigated BSM mixtures. † : Per air dry weight basis; ‡ : Per oven dry weight basis; * : Measured by loss on ignition at 550°C.

Organic Material Amendment	WTR Content (%)†				
	0	2	4	4 [OM+]	10
None					
% WTR‡	-	1.2	2.4	×	6.0
% OM*	2.2	2.7	3.1	×	4.5
Hardwood Bark Mulch					
% WTR‡	-	1.1	2.3	×	×
% Bark Mulch‡	3.2	3.2	3.2	×	×
% OM*	5.6	4.0	5.7	×	×
Leaf Compost					
% WTR‡	-	×	1.9	1.9	×
% Leaf Compost‡	5.2	×	5.3	12.0	×
% OM*	4.6	×	5.4	8.8	×

4.4. Aluminum Hydroxide Amended BSM

Aluminum hydroxide [$Al(OH)_3$] was created and used as an amendment to provide a comparison between the effectiveness of aluminum WTR and pure $Al(OH)_3$ in terms of P adsorption. $Al(OH)_3$ was synthesized by mixing aluminum sulfate [$Al_2(SO_4)_3$] and NaOH in a molar ratio of 1:3 Al:OH. Both compounds were mixed in deionized water under vigorous stirring for 1 hour, allowed to settle for 1 hour, and then the pH was adjusted to approximately 7 with HCl. After pH adjustment, the solution was centrifuged at 4500 rpm for 10 minutes. The supernatant was than decanted and the pellet filtered and collected on a glass fiber filter (Whatman No. 40) under vacuum. It was washed 3 times with ethanol and once with acetone to remove excess sulfate and sodium ions, and air dried overnight (Borggaard et al., 2005).

The oxalate-extractable (amorphous) aluminum content of both constituents and mixes was investigated, as described in Section 4.5. With this information, $Al(OH)_3$ was amended to BSM at a rate analogous to the amorphous Al content of 4%, 2% and 0.5%

WTR, utilizing the logical assumptions that the $Al(OH)_3$ did not include any significant impurities, and was completely amorphous. These mixes are referred to hereafter as 4%, 2%, and 0.5% AH, respectively. In actuality, the mixes are 0.98%, 0.50%, and 0.12% $Al(OH)_3$ on a per air dry weight basis (w/w), respectively. P adsorption isotherms were developed as in section 4.1, using 0.3, 0.9, and 3.0 mg/L P solution and the outlined pH adjustment.

4.5. Total and Oxalate Extractable Elements

Both BSM and WTR were digested per EPA Method 3050B (Acid Digestion of Sediments, Sludges, and Soils) and analyzed by atomic absorbance spectrophotometry for total elemental content of metals, including: Al, Fe, Ca, and Mg. This method releases most elements that may become environmentally available. By design, this method generally does not release those elements bound by silicates, as these are predominantly non-mobile in the environment. In brief, Method 3050B involves digesting 1 g (oven dry weight) of sieved media (< 2 mm) with concentrated nitric acid (HNO_3) for two hours or until a final volume of 5 mL is reached, with HNO_3 addition sufficient for all organic material to be oxidized as evidenced by the cessation of brown fume generation (an indicator of oxidation of organic material). Then, 2 mL water and 2-10 mL hydrogen peroxide (H_2O_2) is added 1 mL at a time until effervescence is minimal or the maximum 10 mL is added. Again, the mixture is digested for 2 hours or to a final volume of 5 mL. Finally, 10 mL concentrated HCl is added and the mixture heated for 15 minutes. It is then filtered through a glass fiber filter (Whatman No. 40), diluted to 100 mL and analyzed by atomic absorbance spectrophotometry.

Determination of oxalate extractable elements; namely iron (Fe), aluminum (Al), and phosphorus (P); was also undertaken. An acid ammonium oxalate solution is used as an extractant to selectively dissolve the amorphous (non-crystalline) fraction of certain soil compounds; namely (hydr)oxides of Al and Fe (McKeague and Day, 1966; 1993). It is this amorphous fraction that provides the majority of the adsorption capacity, and a number of studies have shown a strong correlation between oxalate-extractable aluminum and iron (Al_{ox} + Fe_{ox}) and phosphorus sorption capacity; or, conversely, risk of soil P leaching (Dayton and Basta, 2005). Specifically, a measure known as the Phosphorus Saturation Index (PSI) is often used as a measure of P adsorption/leaching potential, and is defined as:

$$PSI = \frac{P_{ox}}{(Al_{ox} + Fe_{ox})}$$

Where P_{ox}, Al_{ox}, and Fe_{ox} are oxalate-extractable P, Al, and Fe in mmol/kg, respectively. Work has shown that in general, a PSI above 0.25 greatly increases the risk for P leaching from a soil (Chrysostome et al., 2007).

In this research, a modified method of McKeague and Day (1993) was utilized, with a 0.275 M acid ammonium oxalate (0.175 M Ammonium Oxalate + 0.1 M Oxalic Acid) solution used as an extractant, this solution having a pH of approximately 3.4. The pH was adjusted to 3.0±0.1 using 1 N HCl. A 1:40 w/v ratio of media to oxalate solution was used. The single exception to this was the determination of the oxalate-extractable content for WTR alone, for which was used a 1:100 w/v ratio per the recommendation of Dayton and Basta (2005), who showed that a greater ratio is necessary to accurately characterize WTRs because of their much greater amorphous aluminum content.

The oxalate solution was added to the media in a darkened room and shaken on a reciprocating shaker for 2 hours in the dark. This is because the oxalate is photosensitive and may induce the reduction and solubilization of Fe in the media, overstating its amorphous content. Samples were centrifuged for 13 minutes at 2000 rpm after shaking and filtered through a 0.22 μm membrane filter. This filtrate was then analyzed by atomic absorption spectrophotometry for Fe and Al within 1 week.

P was analyzed using the method of Wolf and Baker (1990). In essence this is a modification of the method of Murphy and Riley (1962), with the addition of excess ammonium molybdate. This addition is necessary as oxalate binds molybdate, resulting in insufficient concentration in solution to react with P to form the phosphomolybdic acid which is ultimately measured. This method calls for the use of 0.275 M acid ammonium oxalate solution, and is the impetus behind the use of this higher-than-standard concentration in this work. As with Fe and Al, oxalate extraction samples were analyzed for P within 1 week.

5. Results and Discussion

5.1. Phosphorus Adsorption Isotherm Batch Study Results

Deviation from the standard isotherm method of Nair et al. (1984) must be addressed. Such alterations include the use of KCl as the background electrolyte, as well as the decision to use a media mass of 1.8 g and 45 mL P solution instead of 1 g and 20 mL, respectively, as recommended by Nair et al. The method recommends the use of $CaCl_2$ as a background electrolyte. However, at the higher pH values encountered in these analyses this could result in the precipitation of calcium phosphates, which would misrepresent the phosphorus adsorption capacity of the media. Also, alterations in the sample mass, solution volume, and consequently the equilibration vessel headspace, stemmed from the use of a 5 cm pathlength cuvette for spectrophotometric P concentration determination. It was desired to maximize sorption characterization ability, and so the lowest detection limit was necessary. Because of the large volume of the cuvette, a larger volume of final solution was necessary. To maintain the desired soil:solution ratio, 1.8 g media was selected. The use of both modifications leads to an underestimation of the sorption capacity of the media, and hence results are conservative (Nair et al. 1984).

Results of investigation into pH effects on WTR adsorption capacity are encouraging. WTR acted as a buffer upon pH adjustment, which should be expected because of the pH adjustments routinely performed in drinking water treatment. This resulted in approximately neutral pH after equilibration in most instances. The final pH of solutions containing WTR ranged from approximately 5.9 to 7.4, trending higher with increasing WTR content. Mixtures unamended with WTR had a range of final pH values that was shifted somewhat lower, as these did not benefit from the buffering capacity provided by the WTR, ranging from 4.6 to 7.2. Minimal effect on P adsorption capacity was observed in this pH range, as exemplified in Figures 2 and 3 (note the variations in both the ordinate and abscissa axes among the plots).

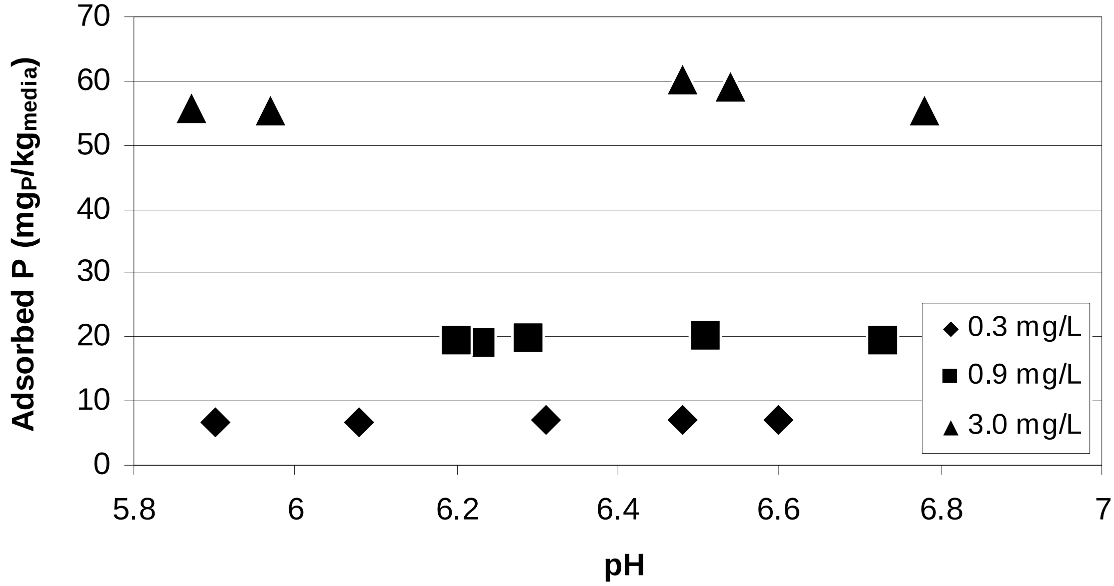

Figure 2. BSM with 2% aluminum WTR P sorption capacity as affected by variation in pH after equilibration with P solution of 0.3, 0.9, and 3.0 mg/L initial concentration.

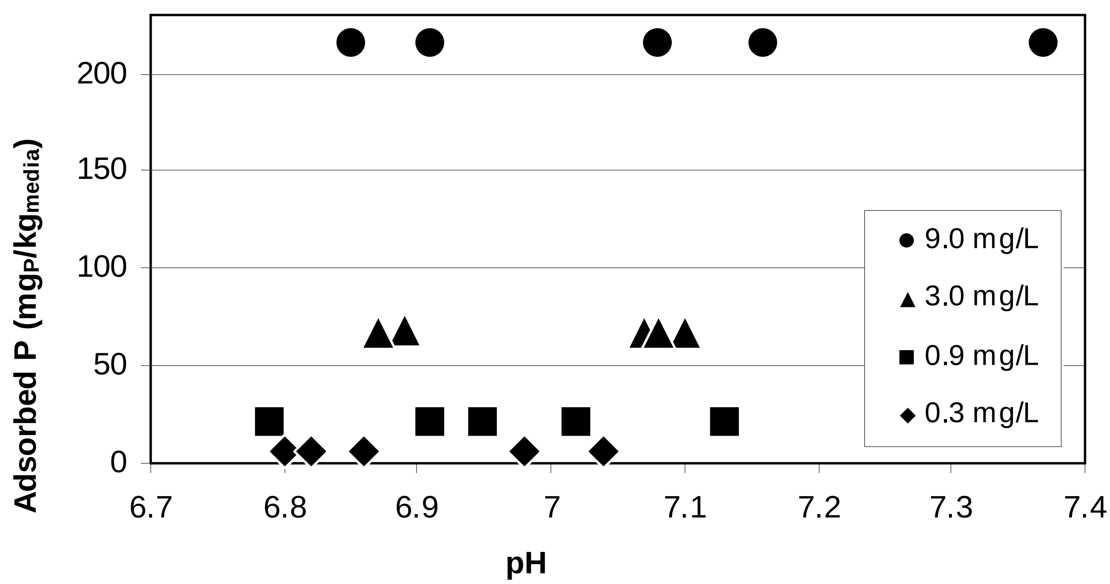

Figure 3. BSM with 10% aluminum WTR P sorption capacity as affected by variation in pH after equilibration with P solution of 0.3, 0.9, 3.0, and 9.0 mg/L initial concentration.

Sorption isotherms for each amendment mixture were plotted as the P concentration remaining in solution after equilibration and the mass of adsorbed P per mass of media. The data are fitted with Freundlich isotherms. Table 2 shows the Freundlich isotherm constants for trendlines. The effect of WTR content on BSM sorption capacity is summarized in Figure 4, and its effect on LFBSM is seen in Figure 5. The BSM and LFBSM media having the same WTR content are compared in Figure 6. These data clearly show that increasing the WTR content of the media increases its P adsorption capabilities. The decreased capacity for the LFBSM mixtures is evident among the unamended mixtures, which is attributed to the reduction in clay content and its associated Al and Fe (hydr)oxides. Inconclusive results were found when comparing mixtures containing larger amounts of WTR, differing depending on the isotherm trendline fitted to the data. Further work is underway to resolve the ambiguity.

Table 2. Freundlich isotherm constants for the investigated BSM mixtures. 0.3, 0.9, and 3.0 mg_P/L solution additions were used containing 0.01 M KCl as a background electrolyte and at pH 4.6 to 7.4. A media to solution ratio of 1:25 was used.

Mixture	K	n
BSM	46.0	1.69
2% WTR	69.3	1.61
4% WTR	106	1.50
10% WTR	361	1.49
LFBSM	21.0	1.37
3% WTR	90.4	1.62
6% WTR	271	1.35
10% WTR	1790	1.02
BSM + HBM	61.0	1.36
2% WTR + HBM	183	1.25
4% WTR + HBM	256	1.22
BSM + LC	17.5	0.778
4% WTR + LC	326	0.857
4% WTR + LC [OM+]	273	0.581

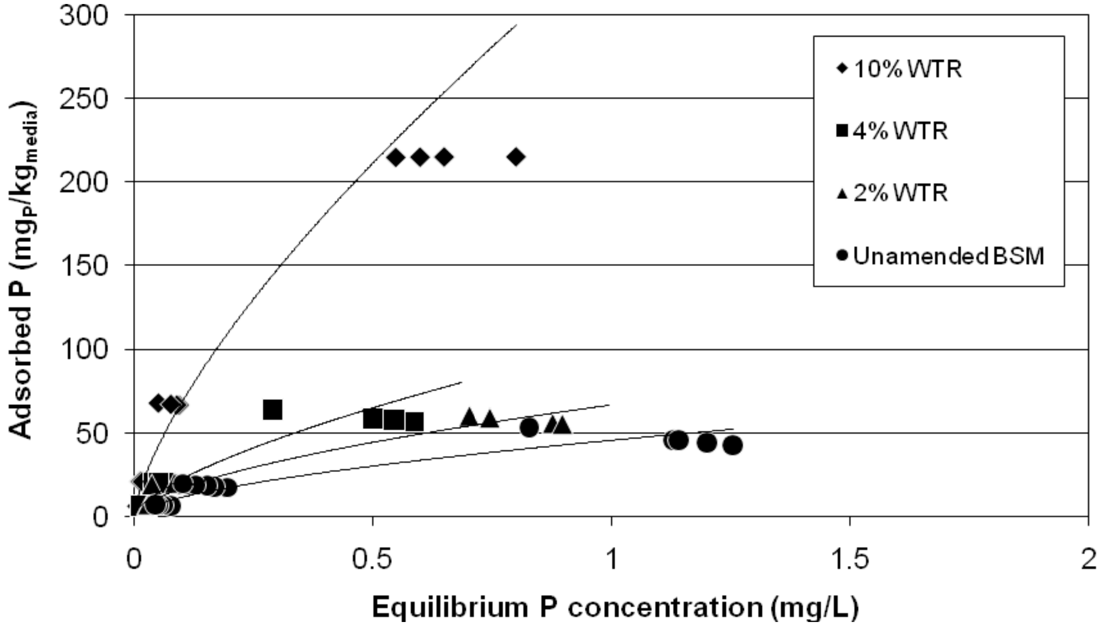

Figure 4. Comparison of P adsorption isotherms for BSM amended with various amounts of aluminum WTR at a pH range of approximately 4.8 to 7.4. Data produced using 0.01 M KCl as a background electrolyte and a media to solution ratio of 1:25. Lines are fitted Freundlich isotherm trendlines.

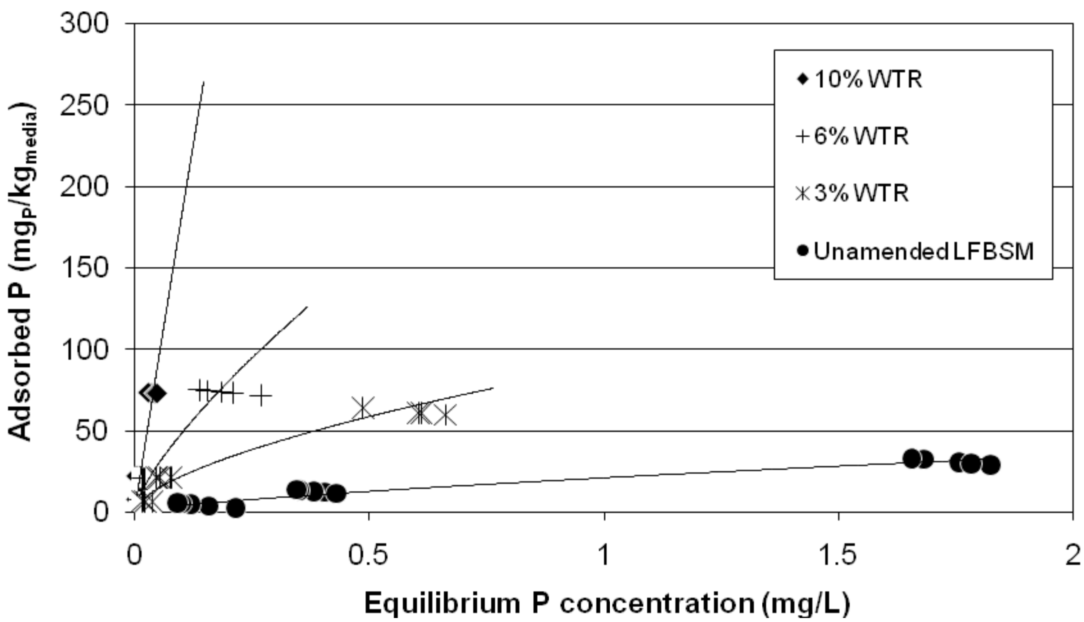

Figure 5. Comparison of P adsorption isotherms for LFBSM amended with various amounts of aluminum WTR at a pH range of approximately 4.6 to 7.3. Data produced using 0.01 M KCl as a background electrolyte and a media to solution ratio of 1:25. Lines are fitted Freundlich isotherm trendlines.

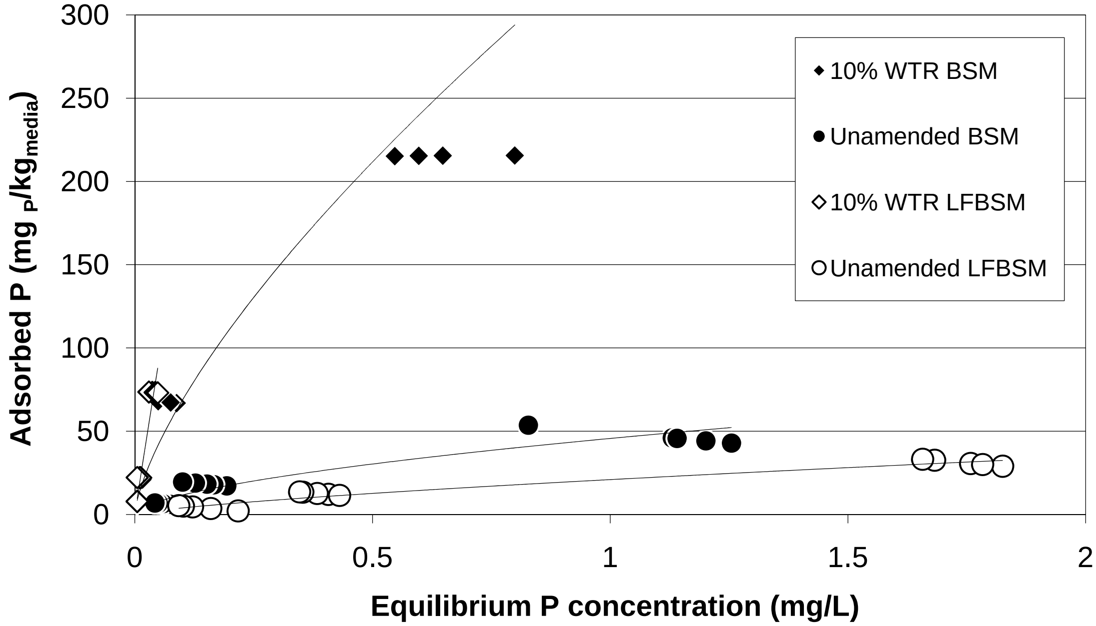

Figure 6. Comparison of P adsorption isotherms for BSM and LFBSM both unamended and amended with 10% aluminum WTR (air dry wt.) at a pH range of approximately 4.6 to 7.4. Data produced using 0.01 M KCl as a background electrolyte and a media to solution ratio of 1:25. Lines are fitted Freundlich isotherm trendlines.

Effects of organic amendments on P adsorption may be seen in the following figures. HBM improved adsorption, shown in Figure 7. This may possibly be due to cationic bridging by $Al(OH)_3$ between soil particles and the mulch, resulting in increased available reactive sites for P capture. This is merely conjecture, however.

As expected, LC addition to the BSM resulted in decreased P adsorption as seen in Figure 8. BSM + LC performed worse than BSM when unamended in all respects. When amended with WTR, though, this was not necessarily the case. The media amended with both WTR and LC performed better at higher P concentrations. This held true even for the 4% WTR amended BSM mixture with additional LC, referred to hereafter as the OM+ mix. However, the 4% WTR + LC performed better only above 0.1 mg P/L, and the OM+ mix performed better only above 0.5 mg P/L when utilizing the fitted trend lines. Therefore, at the concentrations of P found in the majority of stormwater, it is expected for LC to have a detrimental effect on adsorption. It is believed that this loss of adsorptive capacity is caused by leachable P inherent in the LC, which may be released into solution and adversely affect adsorption to the WTR.

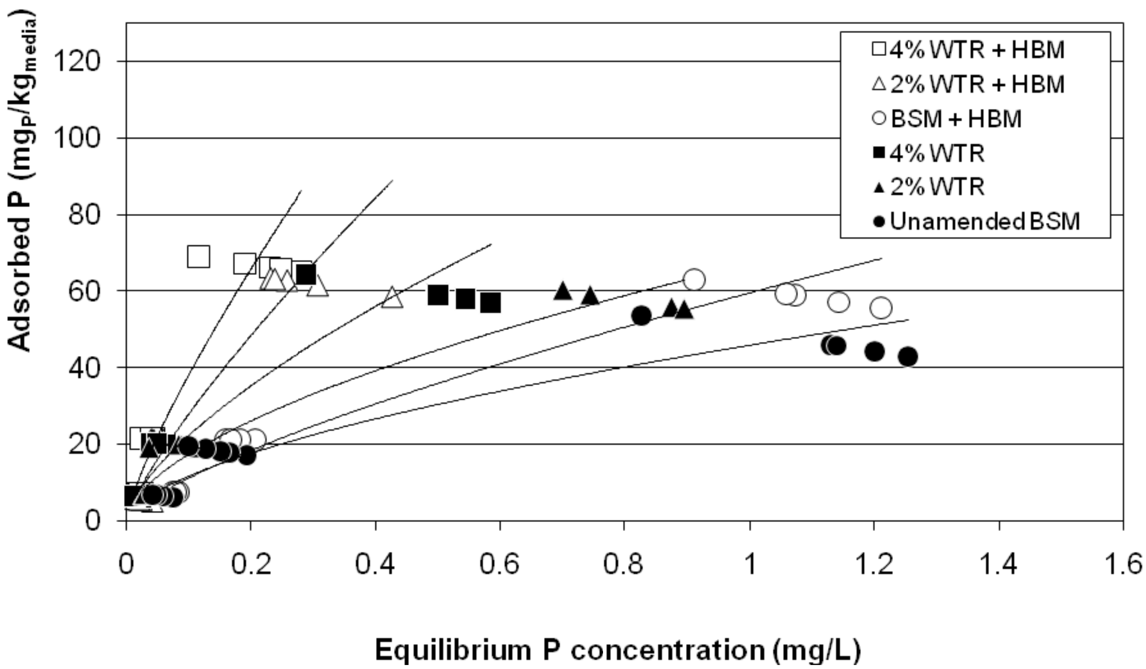

Figure 7. Comparison of P adsorption isotherms for BSM and BSM + HBM both unamended and amended with 2% and 4% aluminum WTR (air dry wt.) at a pH range of approximately 4.8 to 7.4. Data produced using 0.01 M KCl as a background electrolyte and a media to solution ratio of 1:25. Lines are fitted Freundlich isotherm trendlines.

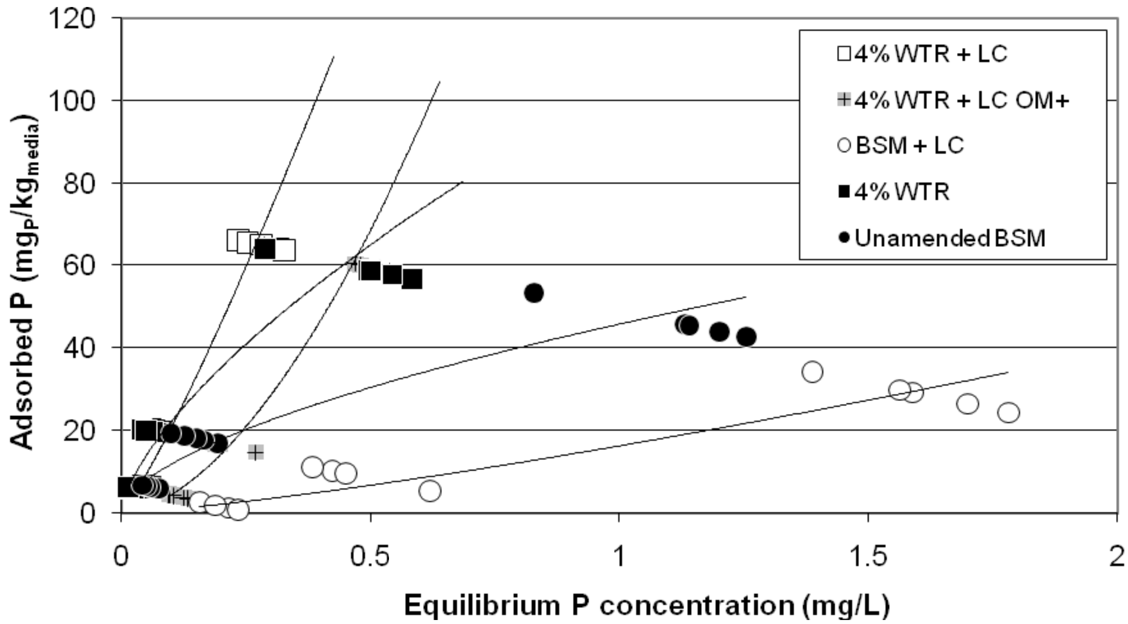

Figure 8. Comparison of P adsorption isotherms for BSM and BSM + LC both unamended and amended with 4% aluminum WTR (air dry wt.), plus 4% WTR with additional LC content. The pH range of the data is approximately 4.8 to 7.4., and was produced using 0.01 M KCl as a background electrolyte and a media to solution ratio of 1:25. Lines are fitted Freundlich isotherm trendlines.

$Al(OH)_3$ was also amended to the BSM to allow comparison with WTR. As explained in Section 4.4, $Al(OH)_3$ was amended on an amorphous Al basis analogous to 4%, 2% and 0.5% WTR. Both 4% AH and 2% AH additions completely or nearly completely removed all added phosphate, resulting in P concentrations after equilibration below the method detection limit. In both instances an adsorption isotherm could not accurately be constructed because of this.

The 0.5% AH addition produced adsorption results from which an isotherm was constructed. In comparison with BSM amended solely with WTR, it performed between the 4% and 10% mixtures. These data are not herein presented though, as the determination of a

0.5% WTR amended BSM isotherm was not undertaken as of the preparation of this report, and a direct comparison of the two amendments is therefore not possible.

The results are interesting, regardless. Although the WTR and AH amendments contain the same amount of amorphous $Al(OH)_3$, the AH amendment adsorbs P much more efficiently and completely. A number of possibilities exist that may explain this phenomena. It may be that the AH amendment possesses a much greater surface area compared to the WTR, as the AH is a powder. It may also be that the WTR is not expressly amorphous, but that some fraction of its mass exists in crystalline form. This would again cause the WTR to possess less surface area compared to the AH. In the end though, both explanations are simply theories meant to try and describe the observed results.

5.2. Phosphorus Saturation Indices of Media

Oxalate extractions and calculation of the PSI for each media were conducted as per Section 4.5. The increasing effectiveness of a given media at P adsorption correlated well with both increasing $(Al+Fe)_{OX}$ content and decreasing PSI (Figures 9 and 10; Table 3). Each mixture of the four amendment types are shown, with each individual point correlating to the data collected from the batch adsorption studies and oxalate extractions for a given amendment content. Points increasing along the abscissa have increasing amorphous Al and Fe content. Understandably, this was produced mainly through increasing Al in each mixture caused by greater WTR content. The ordinate axis is a measure of the equilibrium P adsorption of a mixture with a 0.12 mg P/L solution, which is the average soluble P content of stormwater (US EPA, 1983; Bratieres et al., 2008). This value was determined by the Freundlich fitted trendlines calculated from the batch adsorption data presented in Section 4.

Both graphs (Figures 9 and 10) present a target adsorption of 34 mg/kg soluble P, above which a BSM mixture must perform to meet requirements. As the Washington Metropolitan Area receives approximately 40 in (102 cm) of rain per year, the required P retention capacity of the media was calculated as approximately 34 mg_P/kg_{media} for a bioretention facility sized at 5% of catchment area and having 20 years capacity. Therefore, a BSM mixture must be able to adsorb at least 34 mg_P/kg_{media} at 0.12 mg/L soluble P to provide the necessary stormwater treatment.

It can be seen from Figure 9 that BSM amended with only WTR performed at the threshold requirement when the WTR content was approximately 5% on an air dry weight basis. Therefore, one would expect 5% or greater WTR content in a BSM mixture to provide adequate stormwater treatment for P. Similarly, the LFBSM amended with WTR straddled the threshold between 3% and 6% WTR.

BSM amended with both WTR and HBM crossed the threshold between 2% and 4% WTR. Again, this shows that the HBM improved the P adsorption in the media. However, in considering the WTR and LC amended mixtures, they performed less ideally.

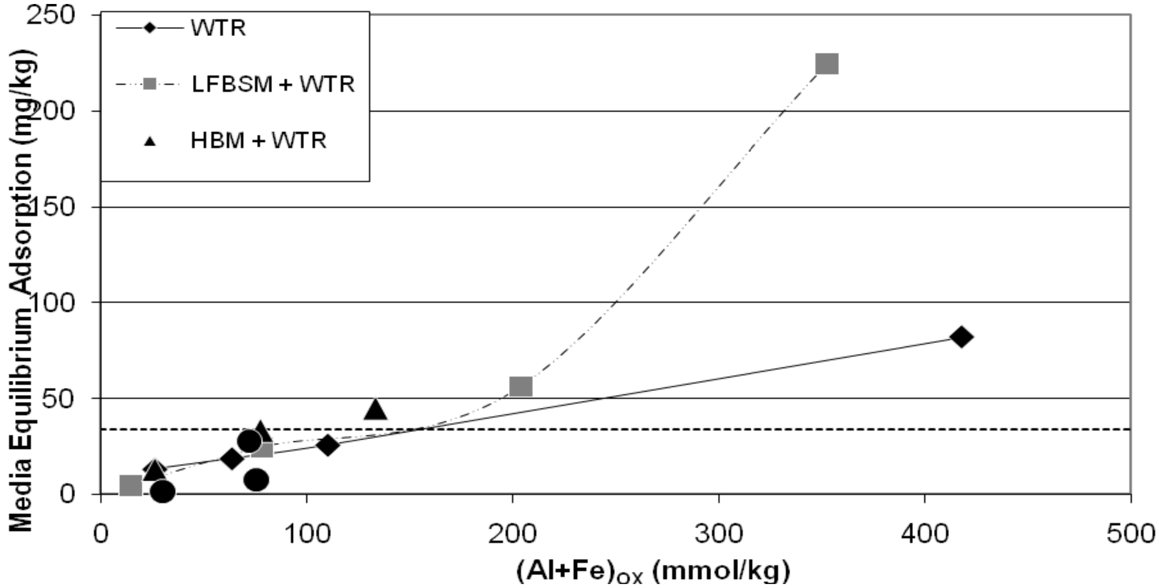

Figure 9. Measured oxalate-extractable Al and Fe content of each media mixture using a 0.125 M acid ammonium oxalate extraction solution, and the interpolated media equilibrium adsorption content. The media equilibrium is calculated for a soluble P concentration of 0.12 mg/L, within a pH range of 4.6 – 7.4.

Table 3. Amorphous (oxalate extractable) P, Fe, and Al contents of BSM mixtures using 0.275 M acid ammonium oxalate at pH 3.0 ± 0.1. PSI is defined at per Section 4.5.

	P_{ox}	Fe_{ox} mmol/kg	Al_{ox}	PSI
BSM	4.04	15.6	10.6	0.154
2% WTR	5.15	15.2	48.4	0.081
4% WTR	6.30	17.2	92.9	0.057
10% WTR	7.39	22.1	395	0.018
LFBSM	1.74	8.86	5.62	0.120
3% WTR	2.55	11.5	66.7	0.033
6% WTR	3.32	11.2	193	0.016
10% WTR	4.60	15.0	338	0.013
BSM + HBM	3.85	17.4	9.35	0.144
2% WTR + HBM	6.88	22.8	54.8	0.089
4% WTR + HBM	5.16	15.4	118	0.039
BSM + LC	5.52	18.5	11.8	0.182
4% WTR + LC	5.59	9.64	62.6	0.077
4% WTR + LC [OM+]	8.79	22.4	53.5	0.116

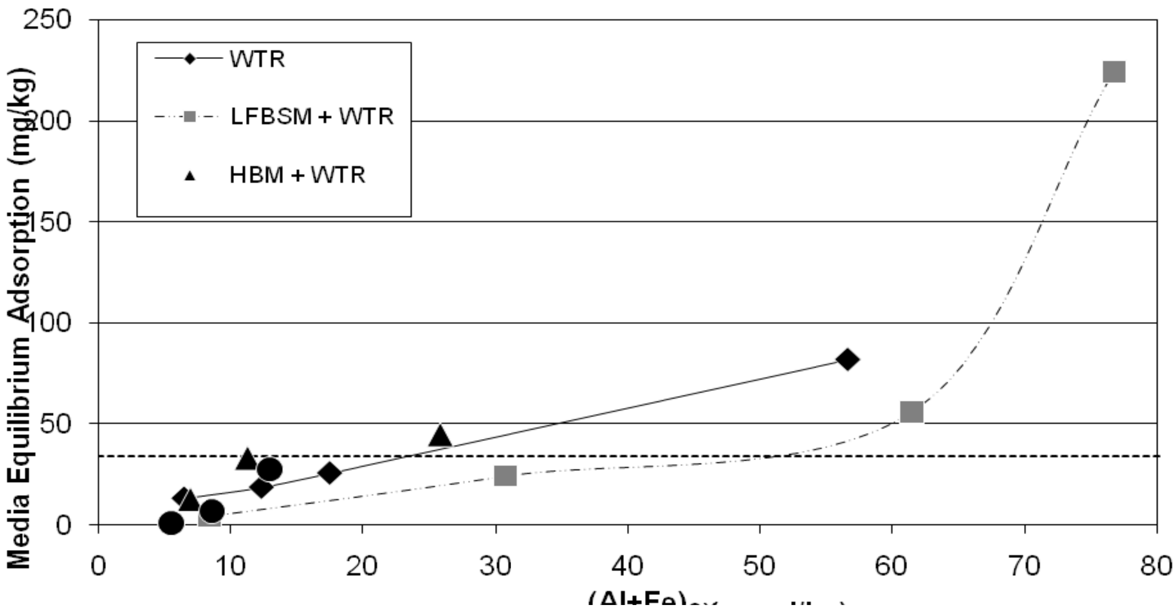

Figure 10. Measured oxalate-extractable Al and Fe content of each media mixture using a 0.125 M acid ammonium oxalate extraction solution normalized over the oxalate-extractable P content, and the interpolated media equilibrium adsorption content. The media equilibrium is calculated for a soluble P concentration of 0.12 mg/L, within a pH range of 4.6 – 7.4.

Figure 10 is similar to Figure 9, with the addition of the abscissa being normalized by the oxalate extractable P content. Ultimately a research goal it to develop a metric for measuring the acceptability of a BSM mixture with regards to its ability to immobilize P. It is believed that considering all three components (oxalate extractable Al, Fe, and P) will produce the most versatile and robust measure. Amorphous Fe and Al content may correlate fairly well with the P adsorption seen in many instances; however, it is believed that P must also be included to account for possible excess P in the mixture which may result in leaching. This concept is captured well in comparing Figures 9 and 10. It is seen in Figure 10 that the LFBSM shifts to the right. In looking at the minimum oxalate ratio (Al+Fe:P) necessary to reach the desired adsorption, the BSM + WTR mixtures should have a ratio of approximately

25 mmol/kg, while the LFBSM+WTR mixtures would need approximately 50 mmol/kg. To meet the requirements for P adsorption, LFBSM mixtures would need either more Al and/or Fe, or less P.

6. Data analysis and future work

Suitability of BSM mixtures for P treatment under flow conditions in small column studies are currently being undertaken. Results of this work are expected to further determine the suitability of WTR and HBM as amendments. P adsorption capacity from the batch studies will be verified, as well as maintenance of desired media flow-through rate. The effect of wetting and drying cycles on media performance will also be investigated.

Upon the completion of the small column studies, larger vegetated column studies will be undertaken as a more comprehensive verification of the recommended BSM mixture. Performance in terms of not only P treatment, but also organic N, ammonia, and oxides of nitrogen will be determined. Verification of *de minimus* free Al leaching from the media will also be undertaken at this point, as well as vegetation survival.

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APPENDIX F:

Illicit Discharge Elimination Process

Process
IDDE Property Owner Notification Letter
'After the Storm' Brochure by EPA
Sample ID Report

ILLICIT DISCHARGE ELIMINATION PROCESS

ILLICIT DISCHARGE ELIMINATION PROCESS

Steps to ID Elimination

Escalating series of actions to be implemented by SHA for Illicit Discharge Connections include:

1. Illicit Discharge Found – Upon notification from the field of a potential illicit discharge from the field inspector, SHA will enter the information into our ID database and assign an ID number to the illicit connection. The ID number will be used in the report.

2. Property Owner Notification – Within 48 hours of discovery of the illicit discharge and receipt of the IDDE report from the field inspector, SHA will notify the property owner by certified letter. A copy of the IDDE report and an educational brochure explaining issues with water quality and stormwater will be included with the certified letter.

2. Notify Local and State NPDES Programs – Within 48 hours of discovery of the illicit discharge and receipt of the IDDE report, SHA will notify the local NPDES coordinator and the MDE NPDES program. A copy of the illicit discharge report will be sent to each of these parties, along with a copy of the certified letter that was sent to the property owner.

3. Re-Investigate Connection – Within a month of sending notification to the property owner and local jurisdiction, SHA will re-investigate the illicit connection to determine if it has been eliminated by the property owner. This will involve sending an inspector out to verify the connection has been removed or document its current state.

4. Document Elimination – If the connection has been eliminated, the SHA will document this in the database and report to MDE NPDES program that the illicit connection has been removed.

5. Pursue Disconnection with Local Jurisdiction – SHA will continue to pursue the disconnection with the local jurisdiction until it is clear that legal action is necessary. This step will involve returning to investigate the connection in response to property owner commitments.

6. Pursue Legal Action if Not Disconnected – If the connection has not been eliminated after attempts through the local jurisdiction, SHA will contact the Environmental Crimes Unit (ECU) of the Attorney General's Criminal Investigations Unit (. We will work with them and the local jurisdiction to get the connection eliminated.

SHA ILLICIT DISCHARGE ELIMINATION PROCESS

Martin O'Malley, *Governor*
Anthony G. Brown, *Lt. Governor*

SHA
State Highway Administration
MARYLAND DEPARTMENT OF TRANSPORTATION

Beverley K. Swaim-Staley, *Secretary*
Neil J. Pedersen, *Administrator*

VIA CERTIFIED MAIL

Date:
ID Number: *(ID NO)*

(OWNERNAME)
(STREETADDRESS1)
(STREETADDRESS2)
(CITY), (STATE) (ZIP)

Dear *(TITLE) (OWNERNAME)*:

THIS LETTER CONTAINS IMPORTANT INFORMATION CONCERNING A POTENTIAL ILLICIT DISCHARGE FROM YOUR PROPERTY.

The Maryland SHA conducts periodic field inspections of SHA drainage and stormwater management facilities in order to assess their condition and identify any illicit connections. Through the National Pollutant Discharge Elimination System (NPDES) regulations, the EPA has required that illicit discharges to stormwater conveyances be identified and removed. State and local laws and/or ordinances also prohibit discharges other than stormwater from draining to surface conveyances without authorization.

HOW DOES THIS AFFECT YOU?

During a recent field inspection conducted along *(ENTER ROADWAY NAME HERE)*, a possible illicit discharge connection from *(ENTER ADDRESS)* to a SHA drainage conveyance was discovered. Photos and a map are attached. **THIS CONNECTION SHOULD BE REMOVED OR PERMANENTLY PLUGGED IMMEDIATELY.** We will re-inspect to ensure this connection has been removed.

This information has also been provided to the *(LOCALJURISDICTION)* NPDES coordinator. If you would like to contact SHA concerning this connection, please send written correspondence to:

SHA NPDES Coordinator - ID Number *(ID NO)*
Highway Hydraulics Division, Mail Stop C-201
Maryland State Highway Administration
707 North Calvert Street
Baltimore, MD 21202

Be sure to reference the ID Number at the top of the letter with your correspondence. If this connection is not permanently disconnected, this matter may be referred to the Maryland Environmental Crimes Unit at (410) 537-3333.

Thank you for your attention to this matter,

Karuna Pujara
Chief, Highway Hydraulics Division

CC: *(TITLE) (LOCALJURISDICTION)*, NPDES Coordinator

My telephone number/toll-free number is 1-888-320-9346
Maryland Relay Service for Impaired Hearing or Speech 1.800.735.2258 Statewide Toll Free
Street Address: 707 North Calvert Street • Baltimore, Maryland 21202 • *Phone* 410.545.0300 • www.sha.maryland.gov

Property Owner Notification Letter

After the Storm

A Citizen's Guide to Understanding Stormwater

EPA 833-B-03-002

January 2003

For more information contact:

or visit

www.epa.gov/npdes/stormwater

www.epa.gov/nps

What is stormwater runoff?

Stormwater runoff occurs when precipitation from rain or snowmelt flows over the ground. Impervious surfaces like driveways, sidewalks, and streets prevent stormwater from naturally soaking into the ground.

Why is stormwater runoff a problem?

Stormwater can pick up debris, chemicals, dirt, and other pollutants and flow into a storm sewer system or directly to a lake, stream, river, wetland, or coastal water. Anything that enters a storm sewer system is discharged untreated into the waterbodies we use for swimming, fishing, and providing drinking water.

The effects of pollution

Polluted stormwater runoff can have many adverse effects on plants, fish, animals, and people.

- Sediment can cloud the water and make it difficult or impossible for aquatic plants to grow. Sediment also can destroy aquatic habitats.
- Excess nutrients can cause algae blooms. When algae die, they sink to the bottom and decompose in a process that removes oxygen from the water. Fish and other aquatic organisms can't exist in water with low dissolved oxygen levels.
- Bacteria and other pathogens can wash into swimming areas and create health hazards, often making beach closures necessary.
- Debris—plastic bags, six-pack rings, bottles, and cigarette butts—washed into waterbodies can choke, suffocate, or disable aquatic life like ducks, fish, turtles, and birds.
- Household hazardous wastes like insecticides, pesticides, paint, solvents, used motor oil, and other auto fluids can poison aquatic life. Land animals and people can become sick or die from eating diseased fish and shellfish or ingesting polluted water.
- Polluted stormwater often affects drinking water sources. This, in turn, can affect human health and increase drinking water treatment costs.

EPA EDUCATIONAL BROCHURE TO BE INCLUDED WITH PROPERY OWNER NOTIFICATION LETTERS (Page 1)

Stormwater Pollution Solutions

Residential

Recycle or properly dispose of household products that contain chemicals, such as insecticides, pesticides, paint, solvents, and used motor oil and other auto fluids. Don't pour them onto the ground or into storm drains.

Lawn care

Excess fertilizers and pesticides applied to lawns and gardens wash off and pollute streams. In addition, yard clippings and leaves can wash into storm drains and contribute nutrients and organic matter to streams.

- Don't overwater your lawn. Consider using a soaker hose instead of a sprinkler.
- Use pesticides and fertilizers sparingly. When use is necessary, use these chemicals in the recommended amounts. Use organic mulch or safer pest control methods whenever possible.
- Compost or mulch yard waste. Don't leave it in the street or sweep it into storm drains or streams.
- Cover piles of dirt or mulch being used in landscaping projects.

Auto care

Washing your car and degreasing auto parts at home can send detergents and other contaminants through the storm sewer system. Dumping automotive fluids into storm drains has the same result as dumping the materials directly into a waterbody.

- Use a commercial car wash that treats or recycles its wastewater, or wash your car on your yard so the water infiltrates into the ground.
- Repair leaks and dispose of used auto fluids and batteries at designated drop-off or recycling locations.

Septic systems

Leaking and poorly maintained septic systems release nutrients and pathogens (bacteria and viruses) that can be picked up by stormwater and discharged into nearby waterbodies. Pathogens can cause public health problems and environmental concerns.

- Inspect your system every 3 years and pump your tank as necessary (every 3 to 5 years).
- Don't dispose of household hazardous waste in sinks or toilets.

Pet waste

Pet waste can be a major source of bacteria and excess nutrients in local waters.

- When walking your pet, remember to pick up the waste and dispose of it properly. Flushing pet waste is the best disposal method. Leaving pet waste on the ground increases public health risks by allowing harmful bacteria and nutrients to wash into the storm drain and eventually into local waterbodies.

Education is essential to changing people's behavior. Signs and markers near storm drains warn residents that pollutants entering the drains will be carried untreated into a local waterbody.

Residential landscaping

Permeable Pavement—Traditional concrete and asphalt don't allow water to soak into the ground. Instead these surfaces rely on storm drains to divert unwanted water. Permeable pavement systems allow rain and snowmelt to soak through, decreasing stormwater runoff.

Rain Barrels—You can collect rainwater from rooftops in mosquito-proof containers. The water can be used later on lawn or garden areas.

Rain Gardens and Grassy Swales—Specially designed areas planted with native plants can provide natural places for rainwater to collect and soak into the ground. Rain from rooftop areas or paved areas can be diverted into these areas rather than into storm drains.

Vegetated Filter Strips—Filter strips are areas of native grass or plants created along roadways or streams. They trap the pollutants stormwater picks up as it flows across driveways and streets.

Commercial

Dirt, oil, and debris that collect in parking lots and paved areas can be washed into the storm sewer system and eventually enter local waterbodies.

- Sweep up litter and debris from sidewalks, driveways and parking lots, especially around storm drains.
- Cover grease storage and dumpsters and keep them clean to avoid leaks.
- Report any chemical spill to the local hazardous waste cleanup team. They'll know the best way to keep spills from harming the environment.

Construction

Erosion controls that aren't maintained can cause excessive amounts of sediment and debris to be carried into the stormwater system. Construction vehicles can leak fuel, oil, and other harmful fluids that can be picked up by stormwater and deposited into local waterbodies.

- Divert stormwater away from disturbed or exposed areas of the construction site.
- Install silt fences, vehicle mud removal areas, vegetative cover, and other sediment and erosion controls and properly maintain them, especially after rainstorms.
- Prevent soil erosion by minimizing disturbed areas during construction projects, and seed and mulch bare areas as soon as possible.

Agriculture

Lack of vegetation on streambanks can lead to erosion. Overgrazed pastures can also contribute excessive amounts of sediment to local waterbodies. Excess fertilizers and pesticides can poison aquatic animals and lead to destructive algae blooms. Livestock in streams can contaminate waterways with bacteria, making them unsafe for human contact.

- Keep livestock away from streambanks and provide them a water source away from waterbodies.
- Store and apply manure away from waterbodies and in accordance with a nutrient management plan.
- Vegetate riparian areas along waterways.
- Rotate animal grazing to prevent soil erosion in fields.
- Apply fertilizers and pesticides according to label instructions to save money and minimize pollution.

Automotive Facilities

Uncovered fueling stations allow spills to be washed into storm drains. Cars waiting to be repaired can leak fuel, oil, and other harmful fluids that can be picked up by stormwater.

- Clean up spills immediately and properly dispose of cleanup materials.
- Provide cover over fueling stations and design or retrofit facilities for spill containment.
- Properly maintain fleet vehicles to prevent oil, gas, and other discharges from being washed into local waterbodies.
- Install and maintain oil/water separators.

Forestry

Improperly managed logging operations can result in erosion and sedimentation.

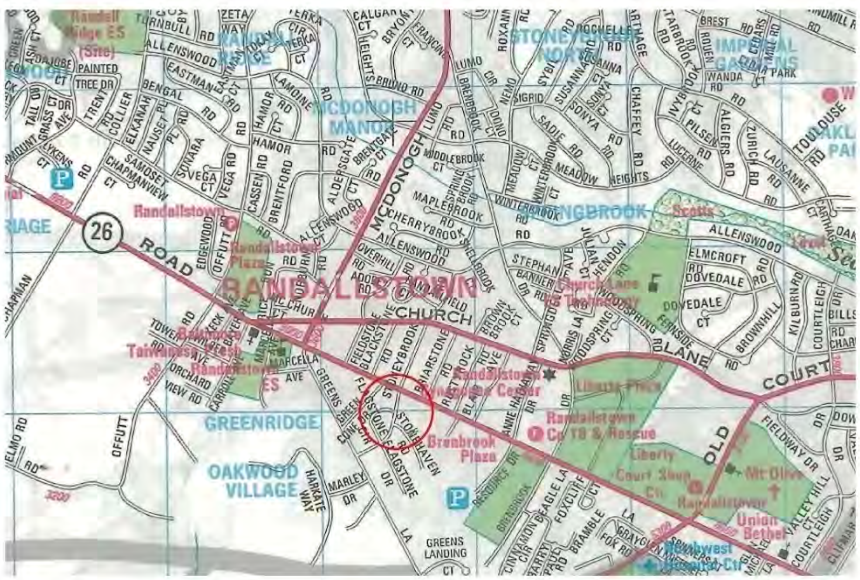
- Conduct preharvest planning to prevent erosion and lower costs.
- Use logging methods and equipment that minimize soil disturbance.
- Plan and design skid trails, yard areas, and truck access roads to minimize stream crossings and avoid disturbing the forest floor.
- Construct stream crossings so that they minimize erosion and physical changes to streams.
- Expedite revegetation of cleared areas.

EPA EDUCATIONAL BROCHURE TO BE INCLUDED WITH PROPERY OWNER NOTIFICATION LETTERS (Page 2)

Illicit Connection 09-ID-BA-001

On October 5, 2009, while performing dry weather inspections of major outfalls owned by Maryland State Highway Administration (MDSHA) in Baltimore County, inspectors observed a small yet constant amount of discharge at a 48" RCP outfall (Structure No. 0300728.001). The small amount of discharge was difficult to collect for sampling, so the inspectors proceeded upstream in the storm drain system to attempt to isolate where it entered the system. The discharge was observed to originate from a small PVC outfall at a private residence. The outfall discharged to a small (~6" wide) concrete channel on the property that conveyed the water into the gutter along Stoneybrook Road and ultimately into a roadway inlet (Structure No. 0300728.005). The gutter appears to be near the property boundary of 3510 Stoneybrook Road and 8900 Liberty Road, but given the observed direction of the PVC outfall, it was assumed that the source of the discharge was 3510 Stoneybrook Road.

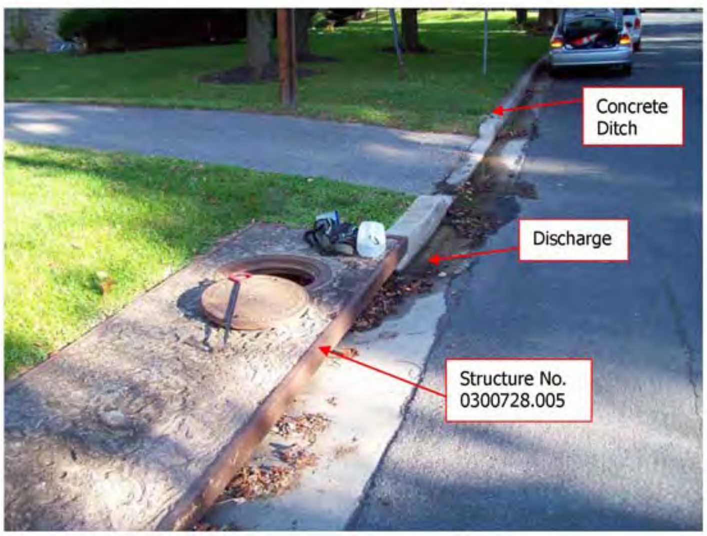
A portion of the discharge was collected from the inlet and illicit discharge sampling was performed. The sample was foamy, cloudy and grey and had a sweet smell commonly associated with detergents in laundry wastewater. The testing identified the presence of Detergents (0.7 mg/l) and Ammonia (2.4 mg/l) above the allowable limits.



Baltimore County ADC Map 24, page 28

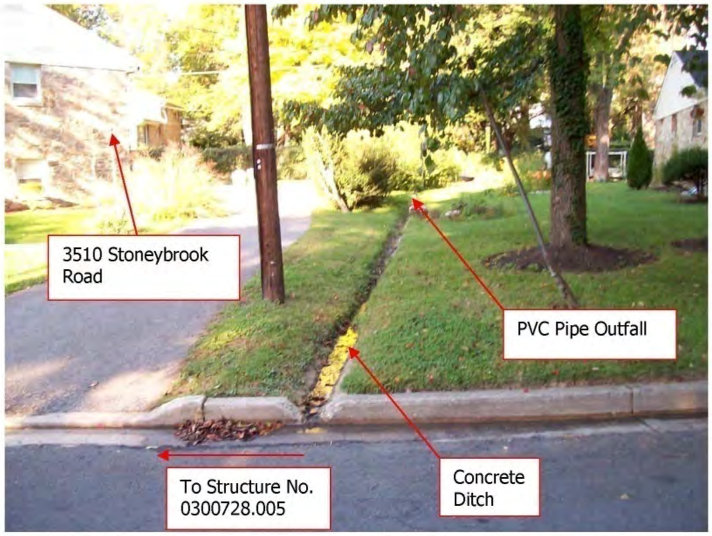
ILLICIT DISCHARGE REPORT INCLUDED WITH PROPERTY OWNER NOTIFICATION (Page 1)

Downstream SHA Structure # 0300728.001



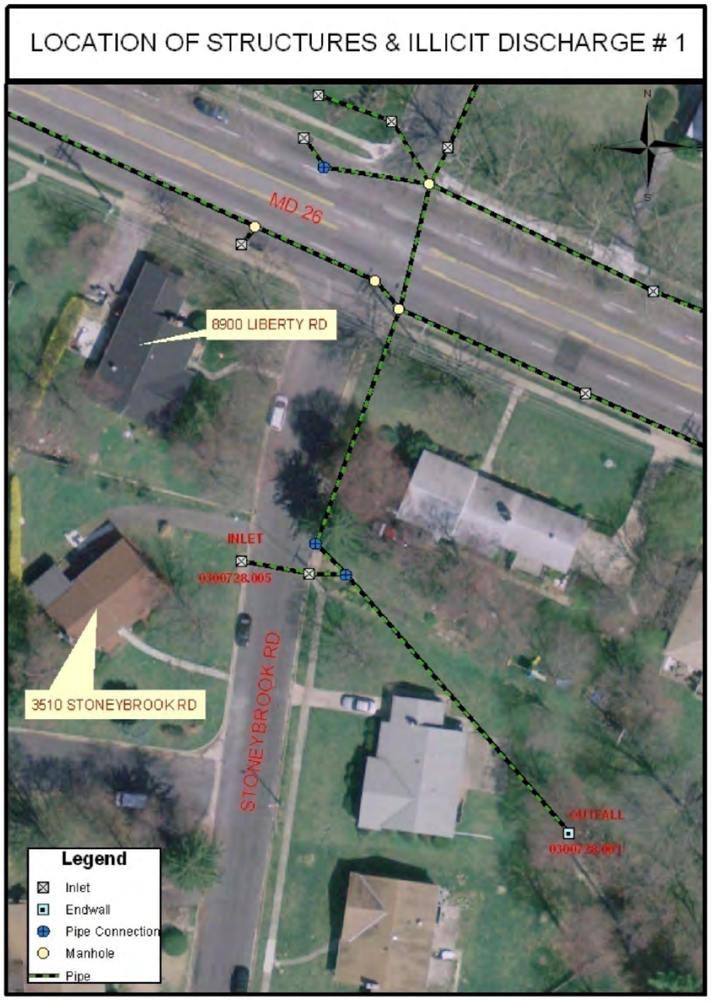
Discharge into inlet along Stoneybrook Road

ILLICIT DISCHARGE REPORT INCLUDED WITH PROPERTY OWNER NOTIFICATION (Page 2)



Concrete ditch discharging into roadway gutter

ILLICIT DISCHARGE REPORT INCLUDED WITH PROPERTY OWNER NOTIFICATION (Page 3)

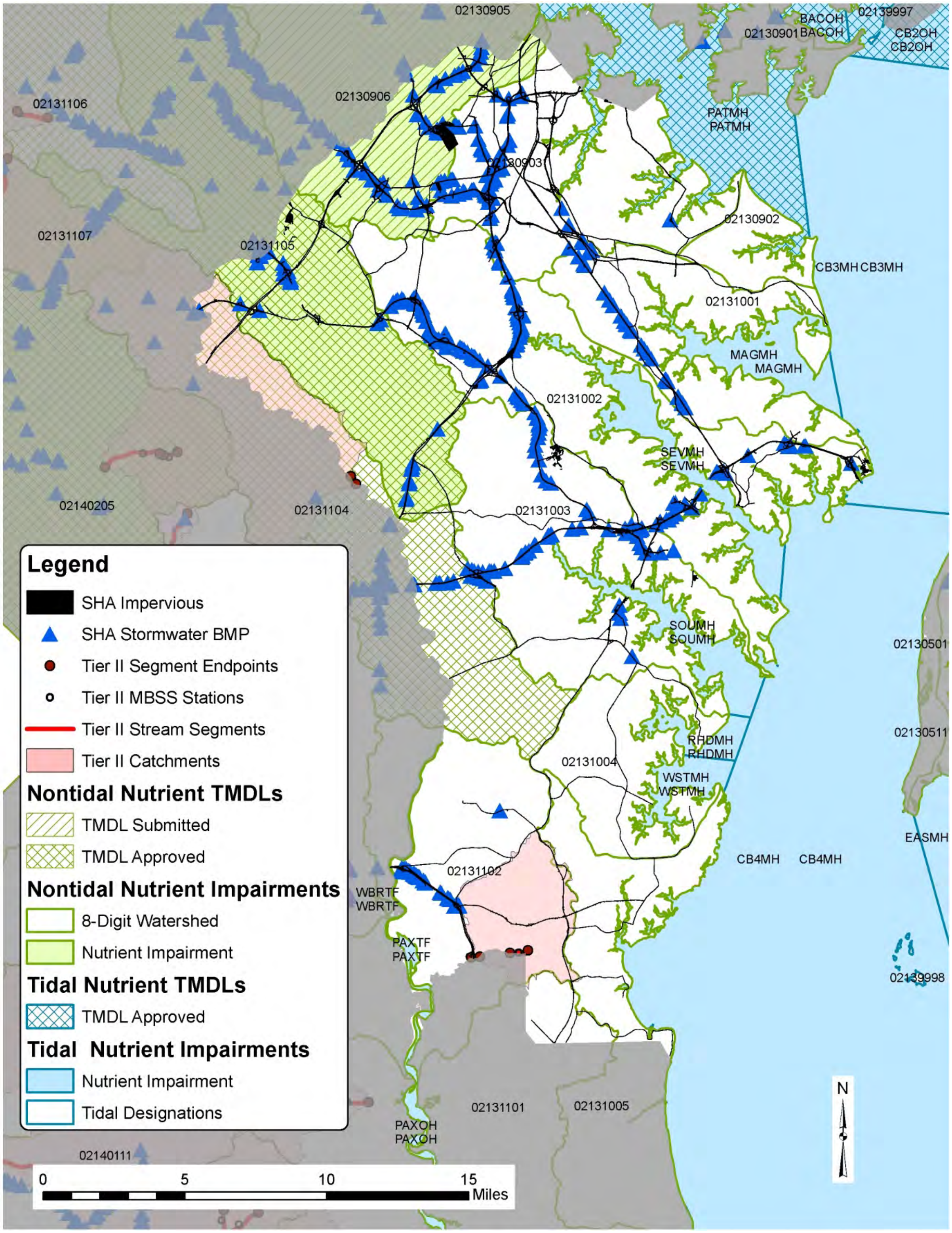


ILLICIT DISCHARGE REPORT INCLUDED WITH PROPERTY OWNER NOTIFICATION (Page 4)

APPENDIX G:

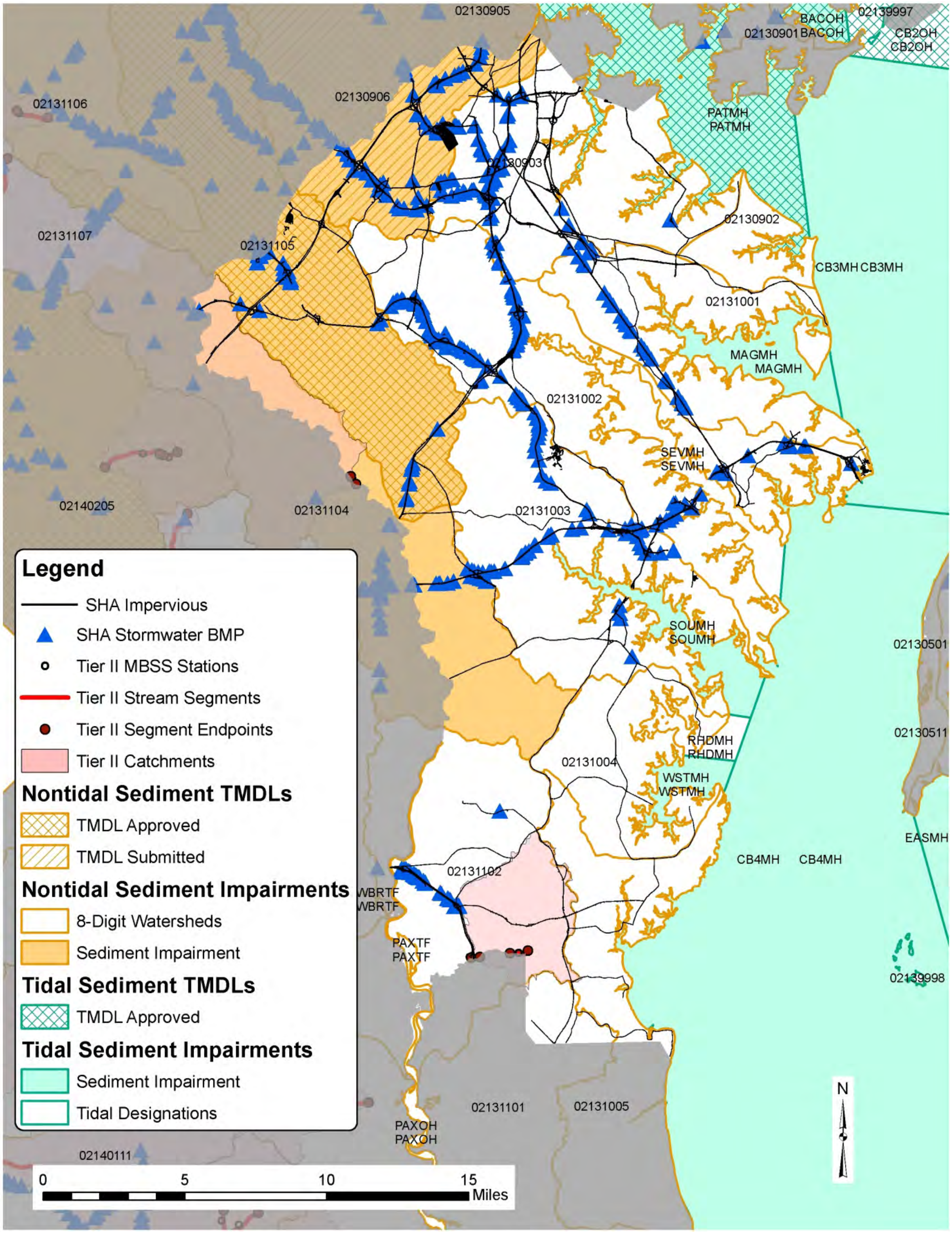
TMDL Mapping with SHA Impervious & Stormwater BMPs: Nutrients & Sediments

Anne Arundel County
Baltimore County
Carroll County
Charles County
Frederick County
Harford County
Howard County
Montgomery County
Prince George's County



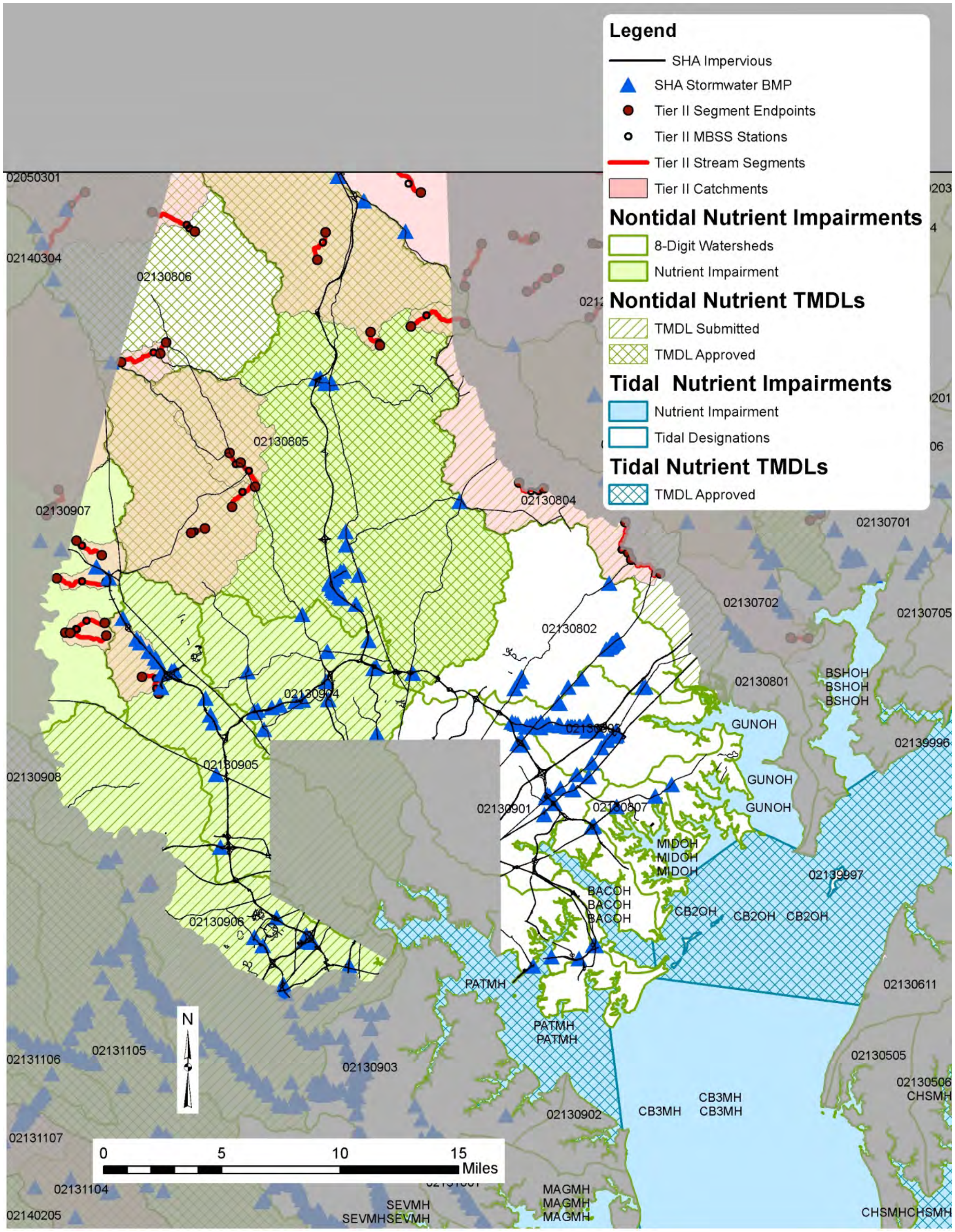
Anne Arundel County – Nutrients

TMDL MAPPING WITH SHA IMPERVIOUS & SWM BMPs: NUTRIENTS & SEDIMENT



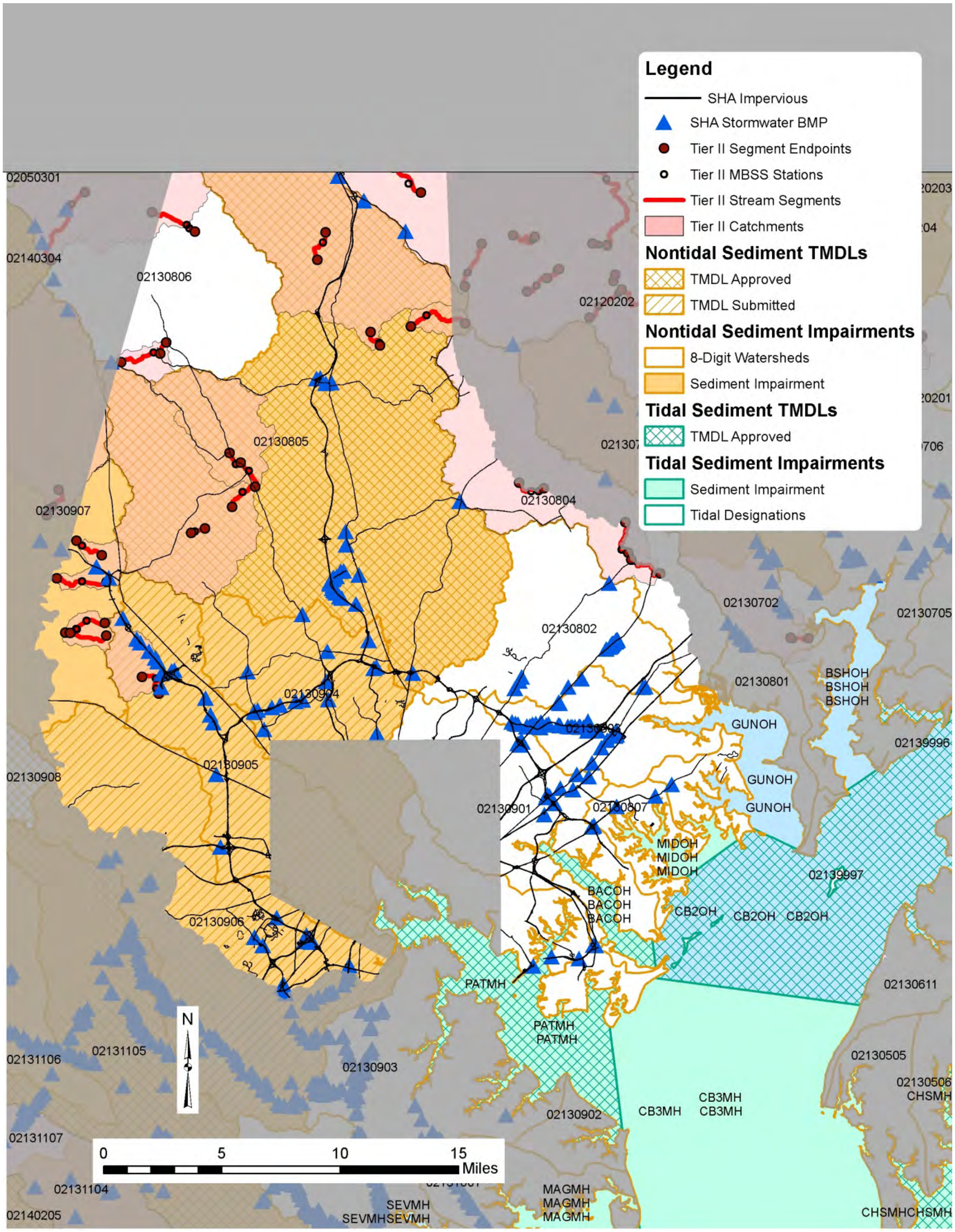
Anne Arundel County – Sediment

TMDL MAPPING WITH SHA IMPERVIOUS & SWM BMPs: NUTRIENTS & SEDIMENT

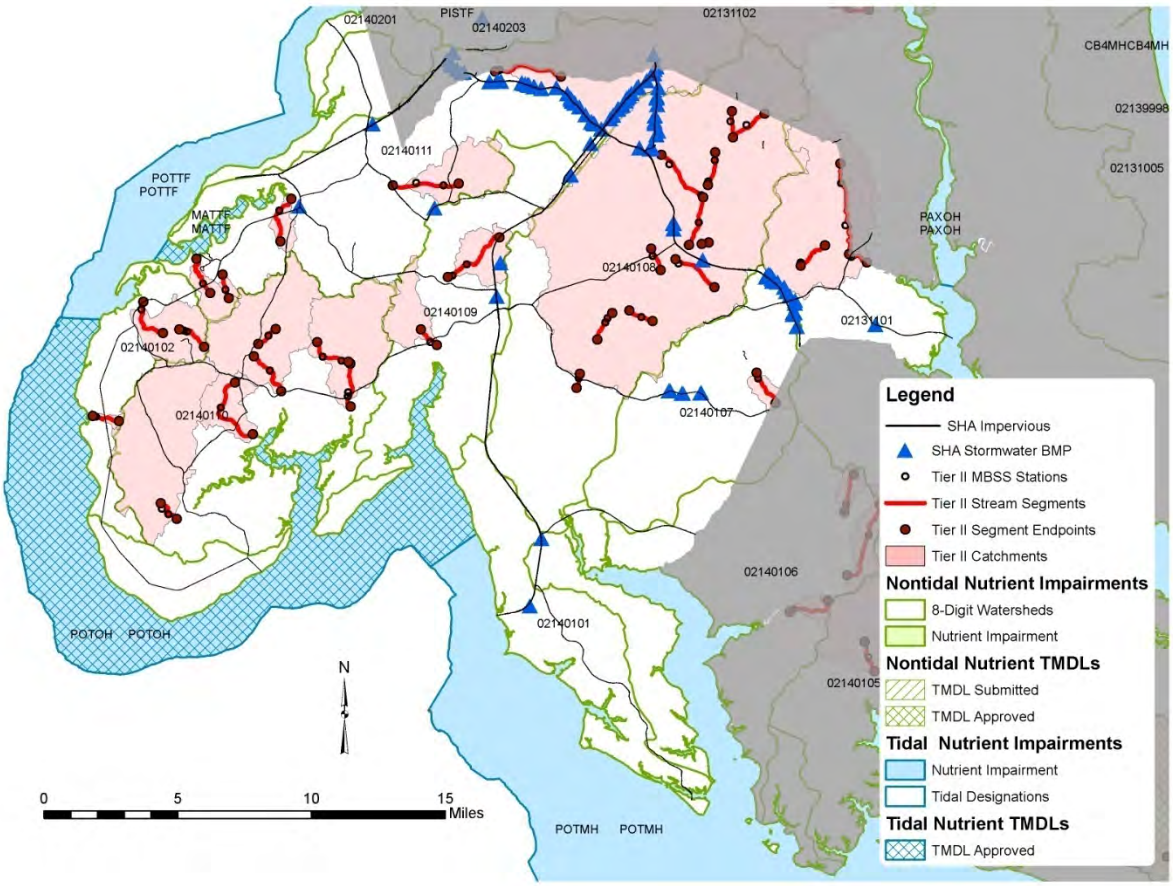


Baltimore County – Nutrients

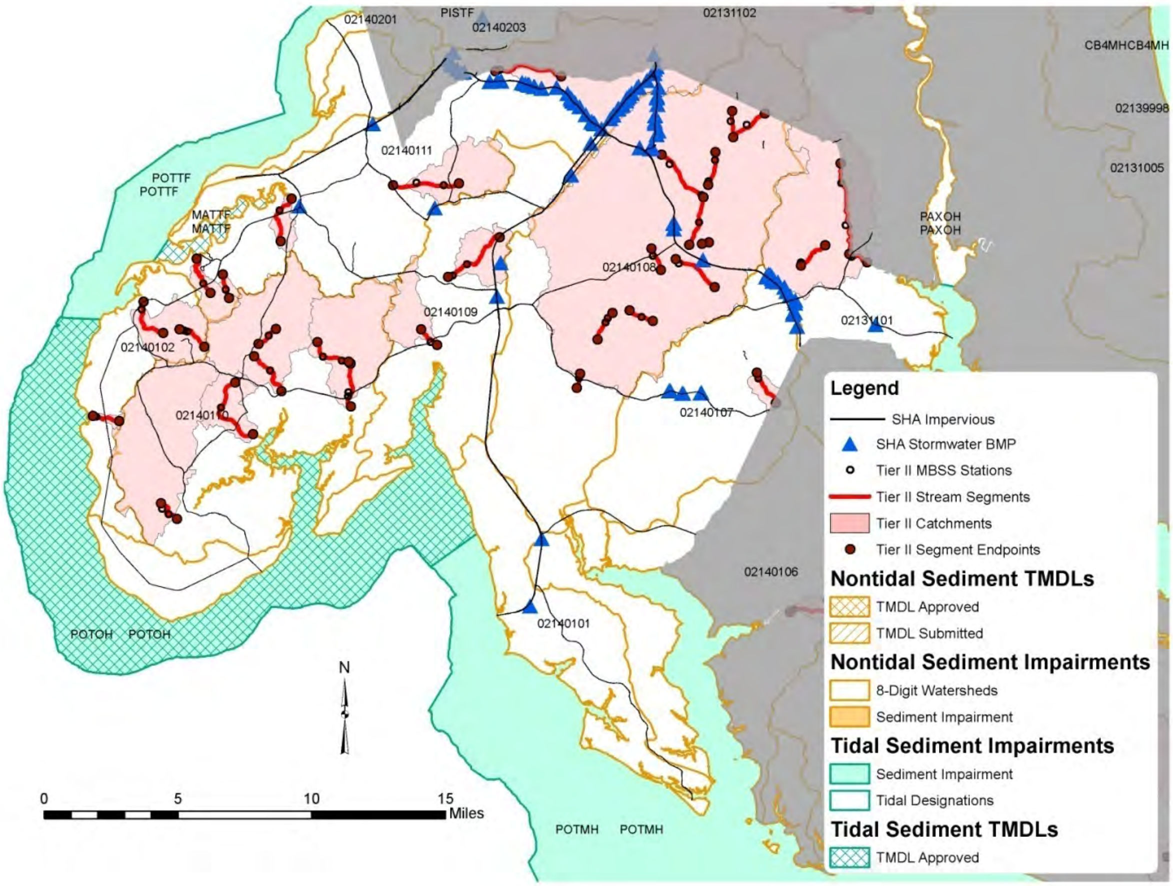
TMDL MAPPING WITH SHA IMPERVIOUS & SWM BMPs: NUTRIENTS & SEDIMENT



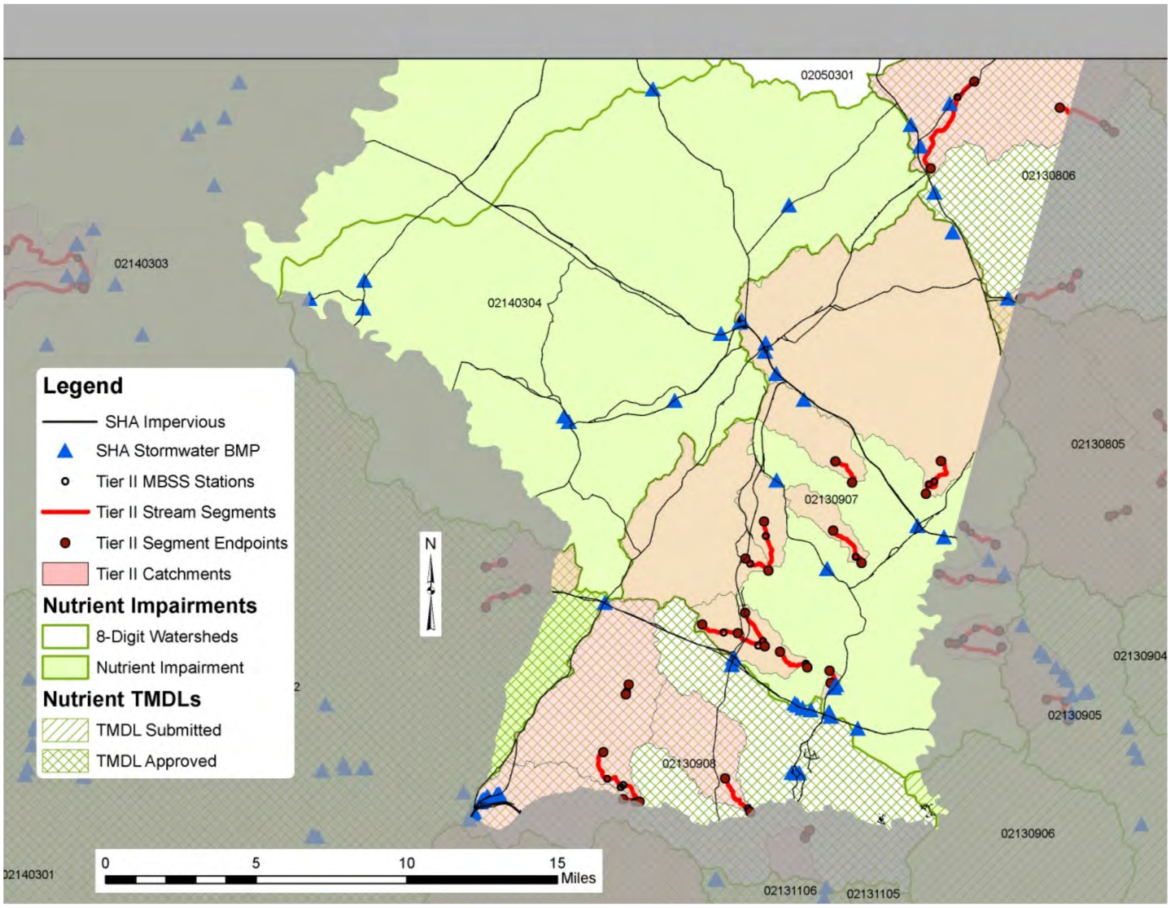
Baltimore County – Sediment



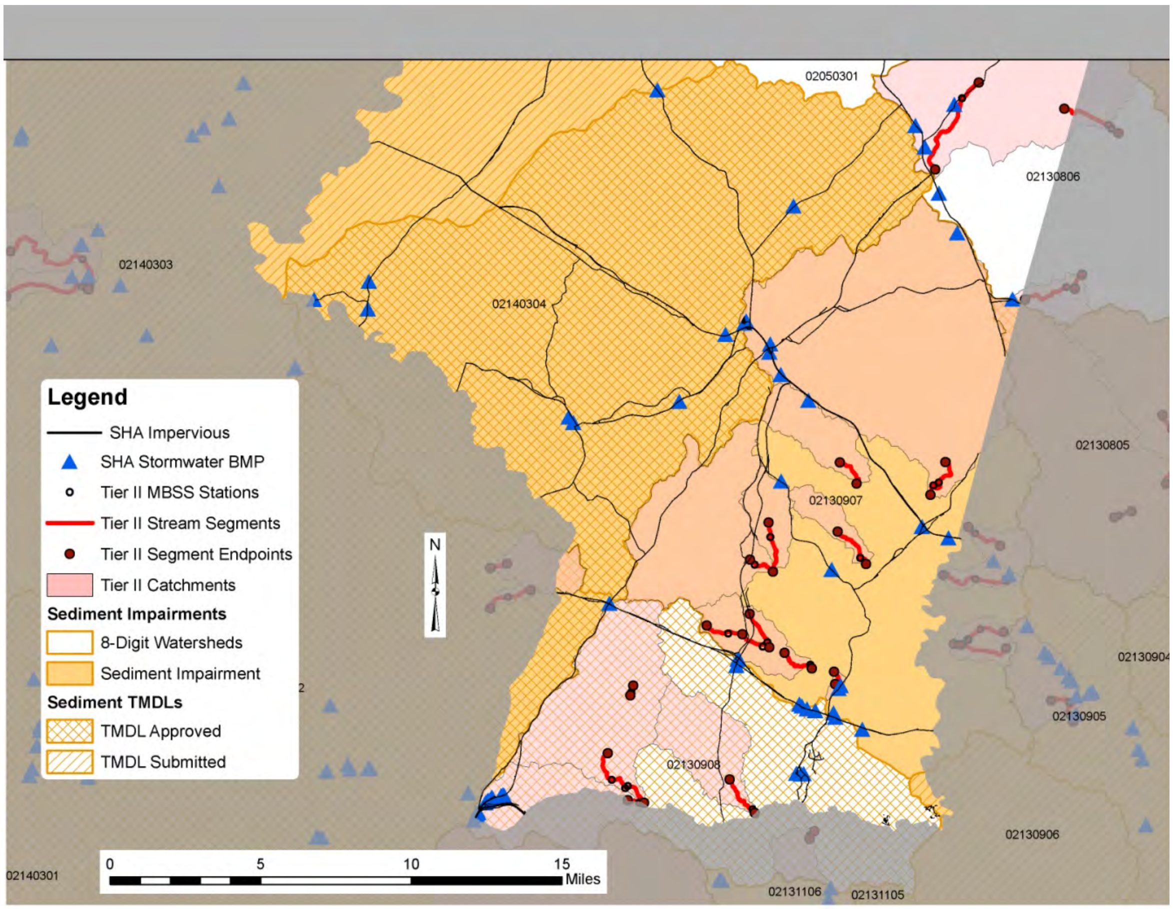
Charles County – Nutrients



Charles County – Sediments

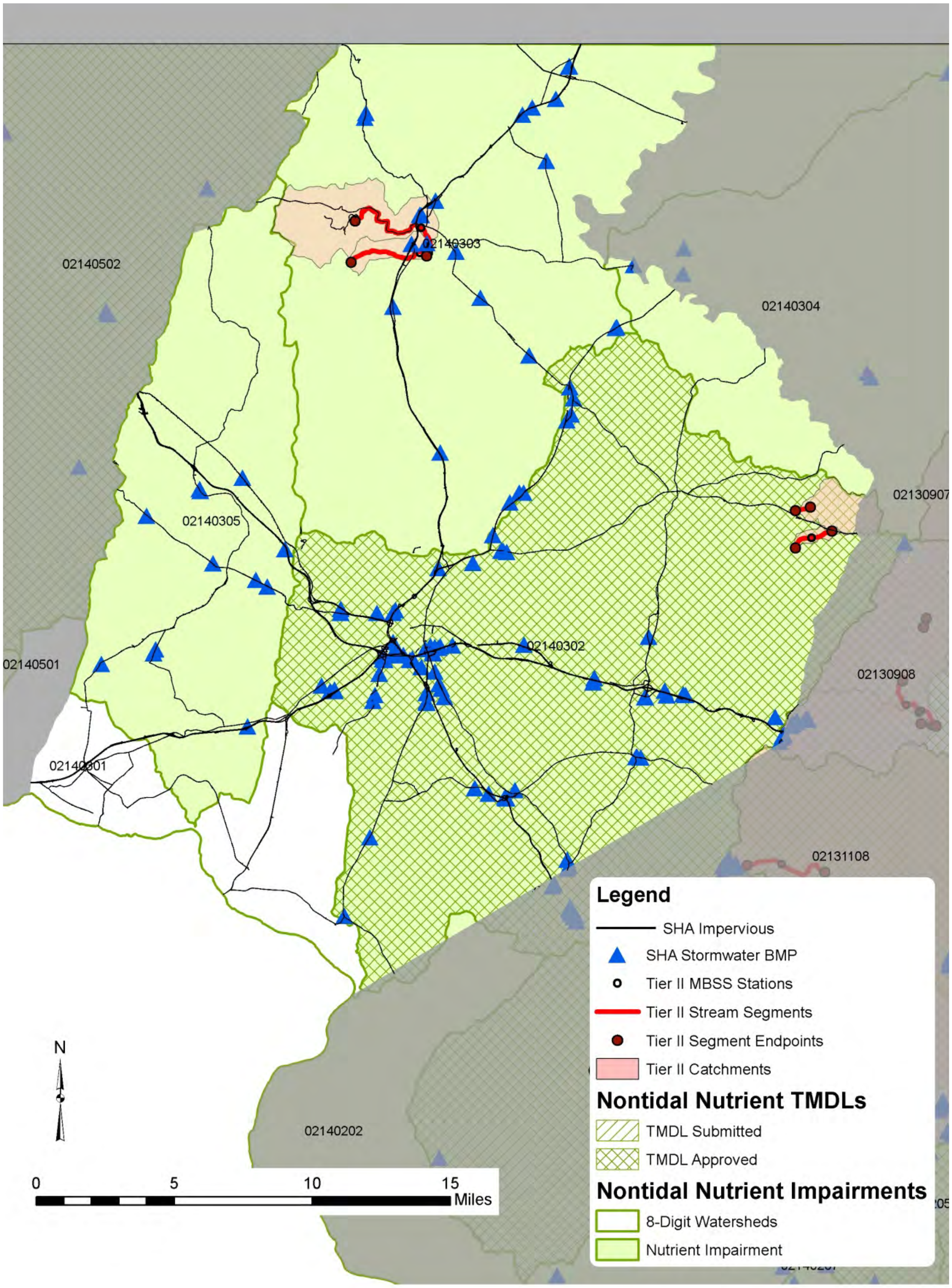


Carroll County – Nutrients



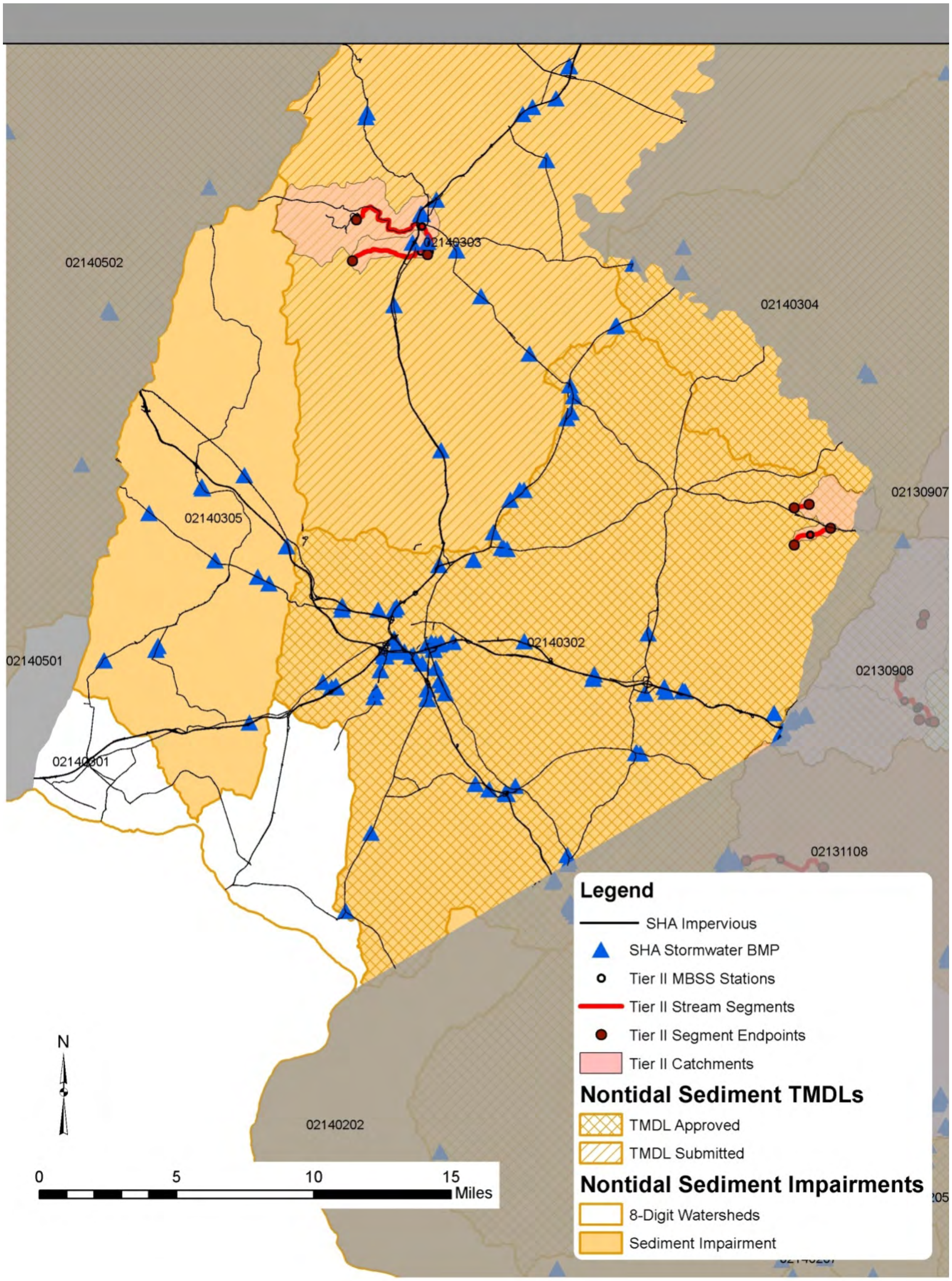
Carroll County – Sediment

TMDL MAPPING WITH SHA IMPERVIOUS & SWM BMPs: NUTRIENTS & SEDIMENT

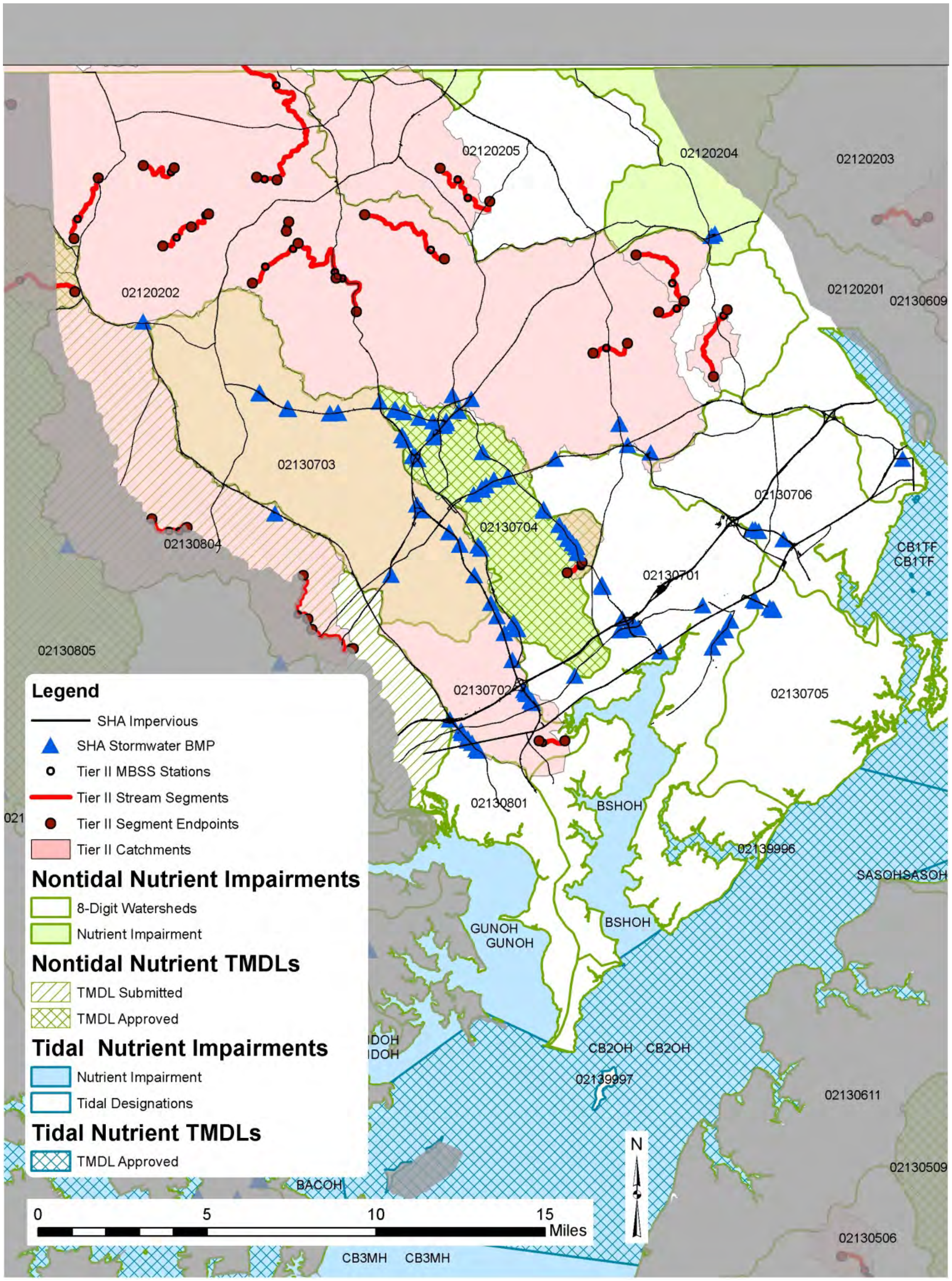


Frederick County – Nutrients

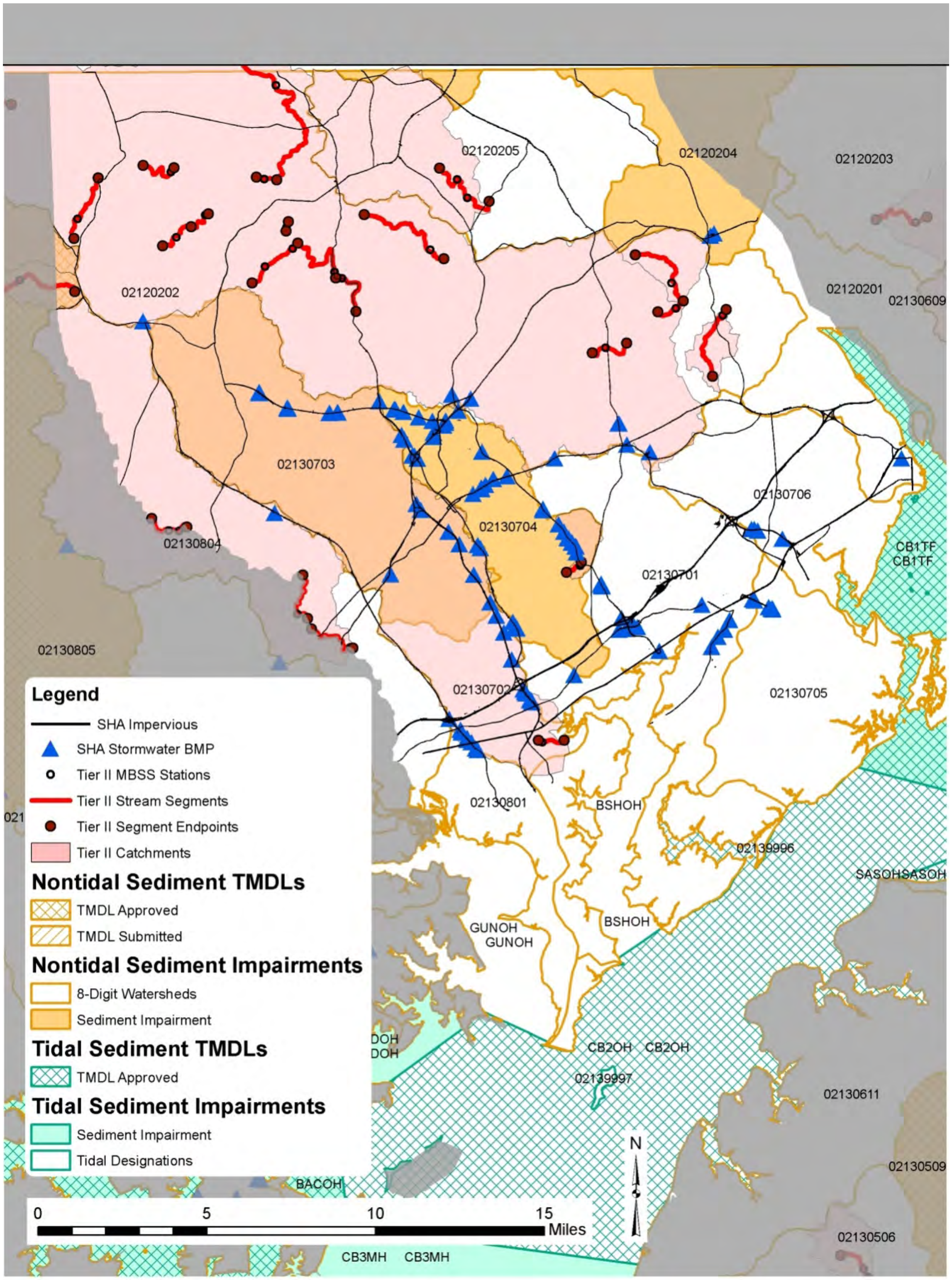
TMDL MAPPING WITH SHA IMPERVIOUS & SWM BMPs: NUTRIENTS & SEDIMENT



Frederick County – Sediment

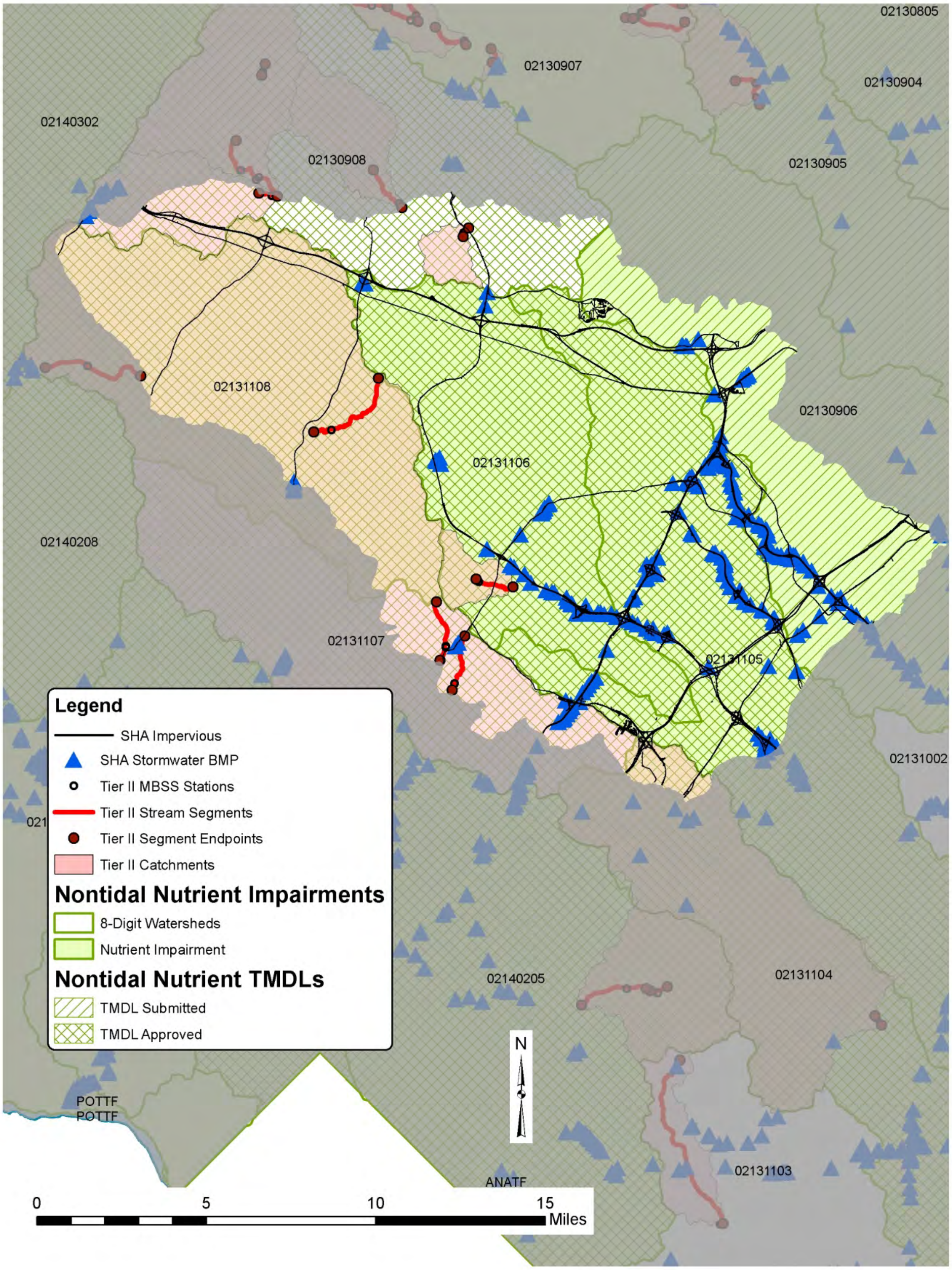


Harford County – Nutrients



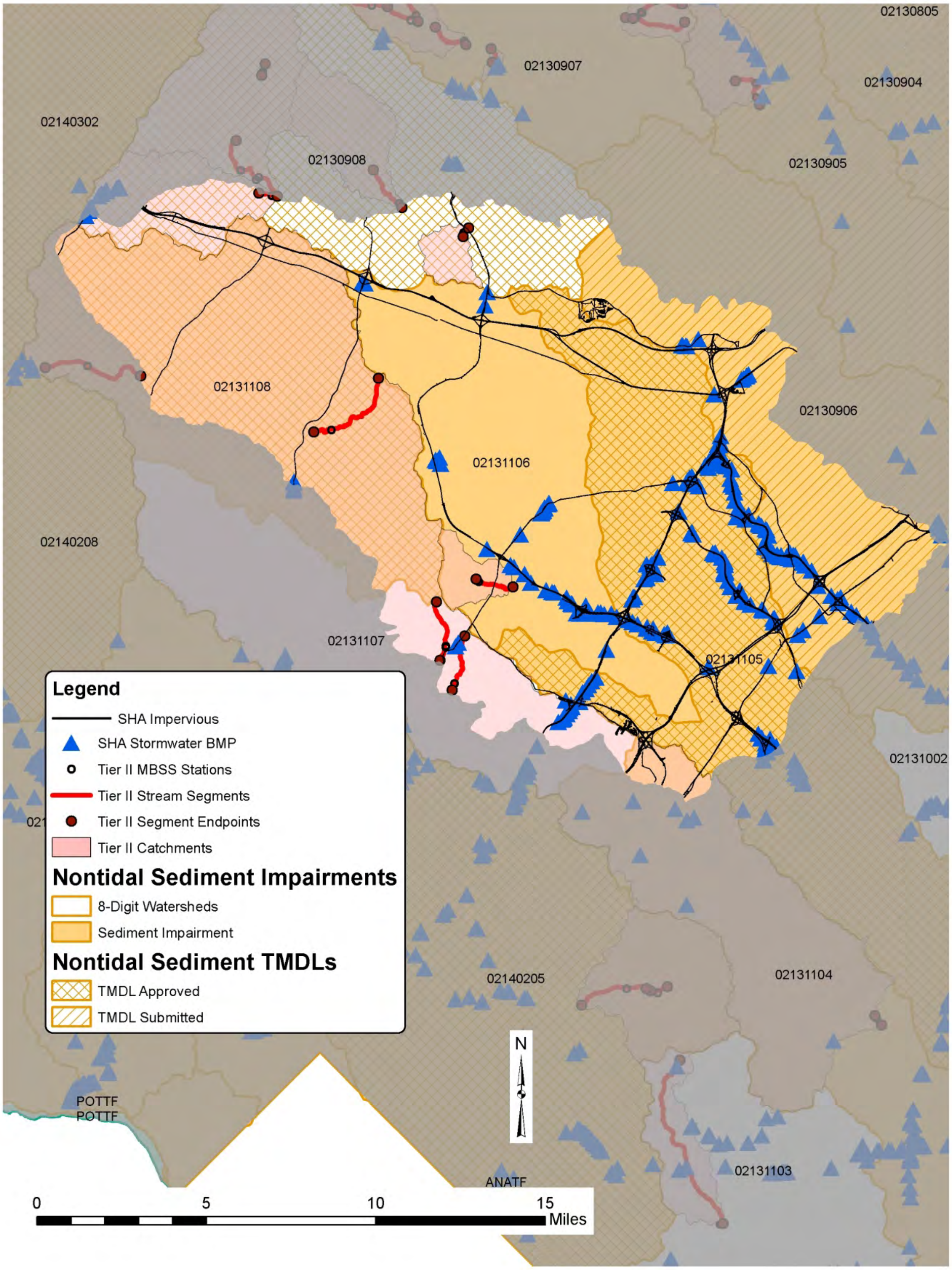
Harford County – Sediment

TMDL MAPPING WITH SHA IMPERVIOUS & SWM BMPs: NUTRIENTS & SEDIMENT



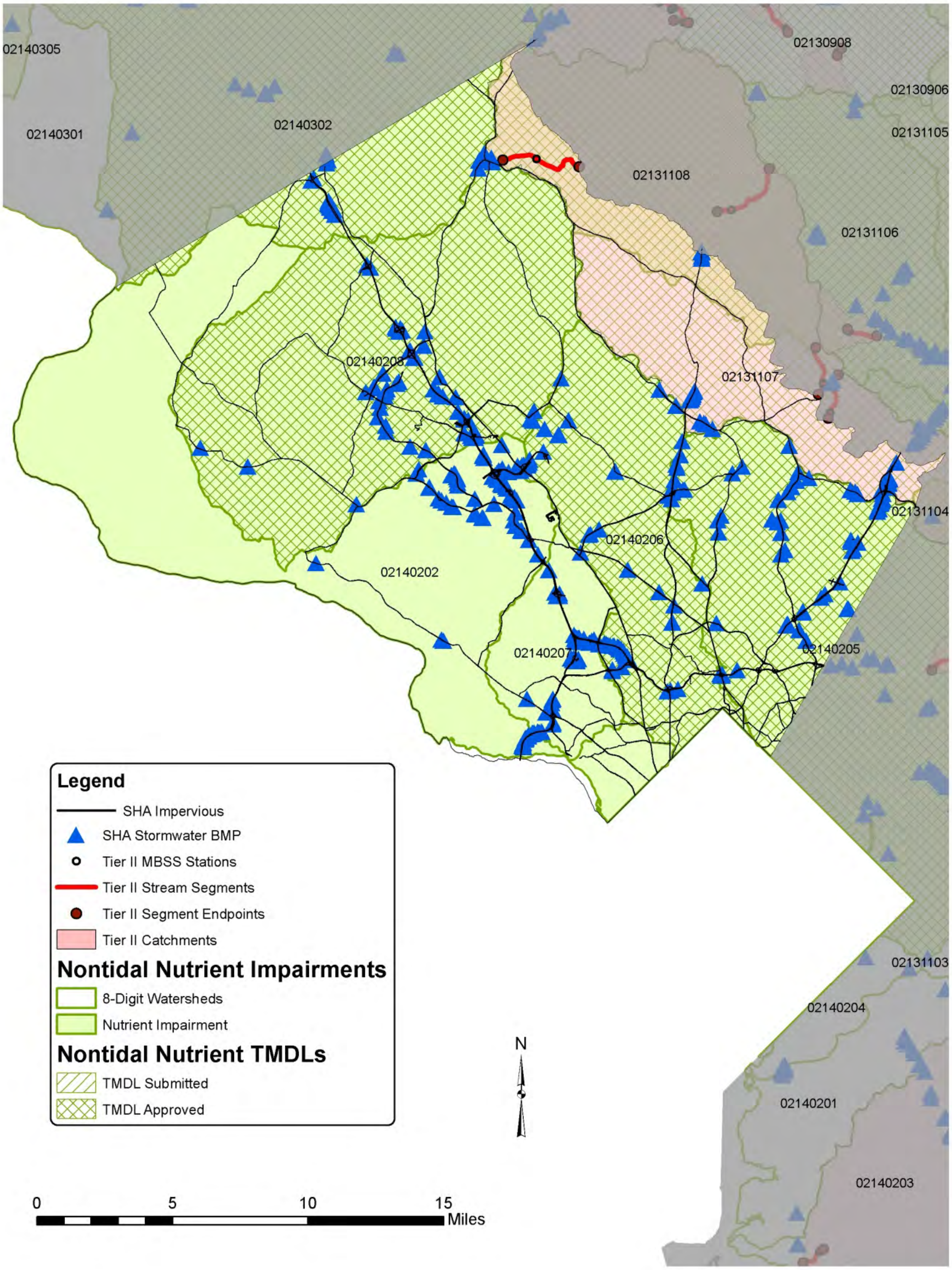
Howard County – Nutrients

TMDL MAPPING WITH SHA IMPERVIOUS & SWM BMPs: NUTRIENTS & SEDIMENT

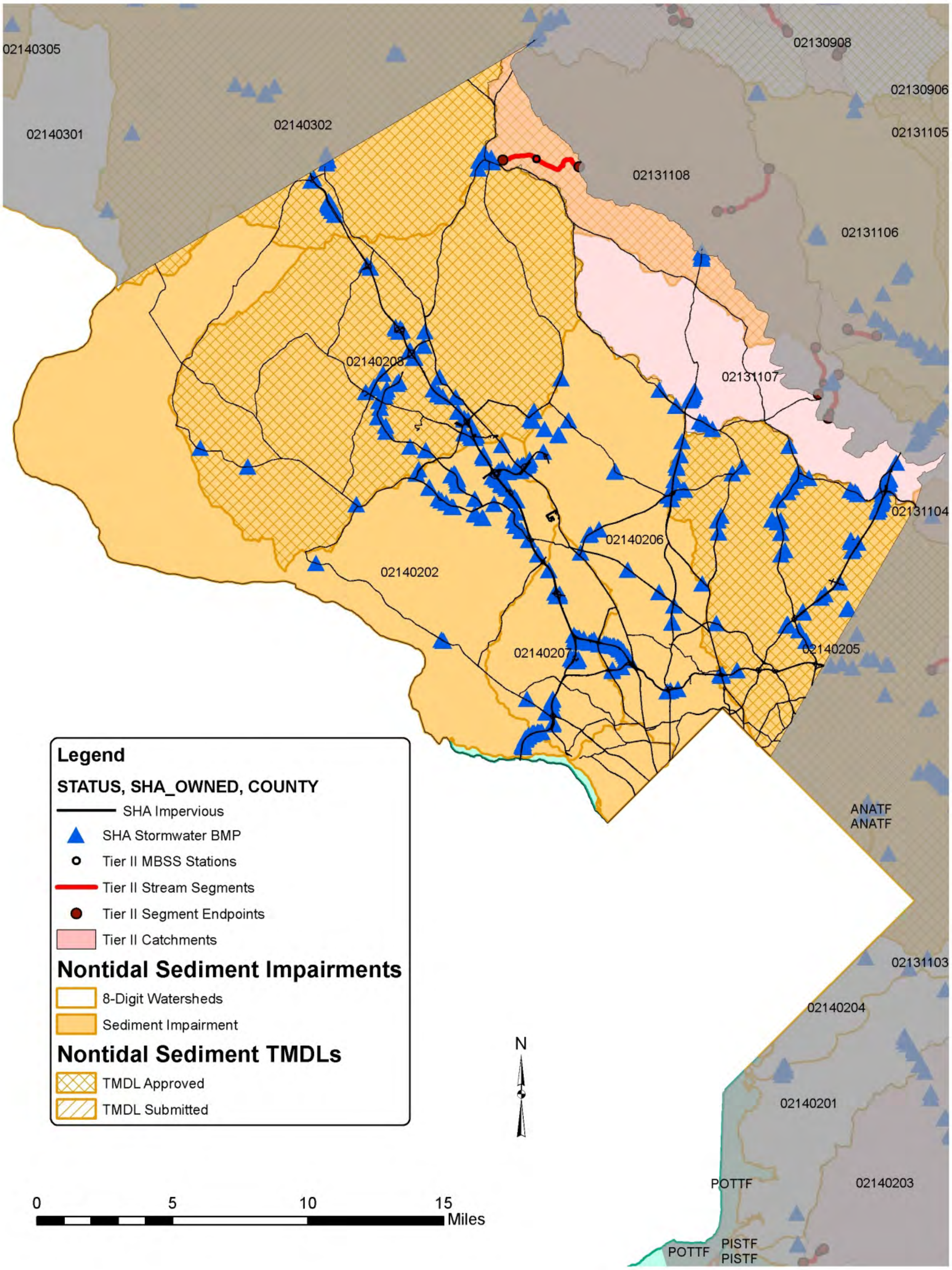


Howard County – Sediment

TMDL MAPPING WITH SHA IMPERVIOUS & SWM BMPs: NUTRIENTS & SEDIMENT

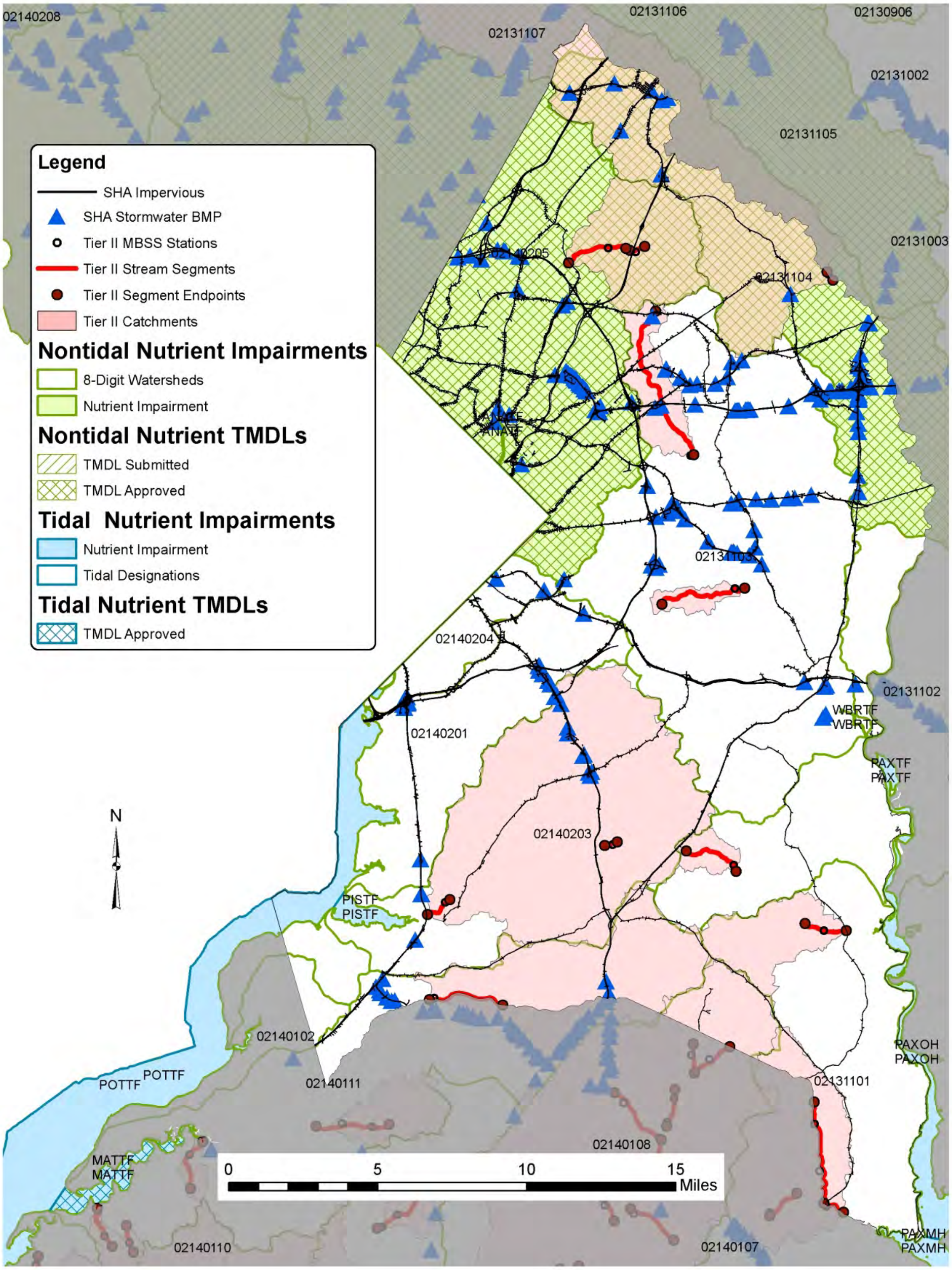


Montgomery County – Nutrient

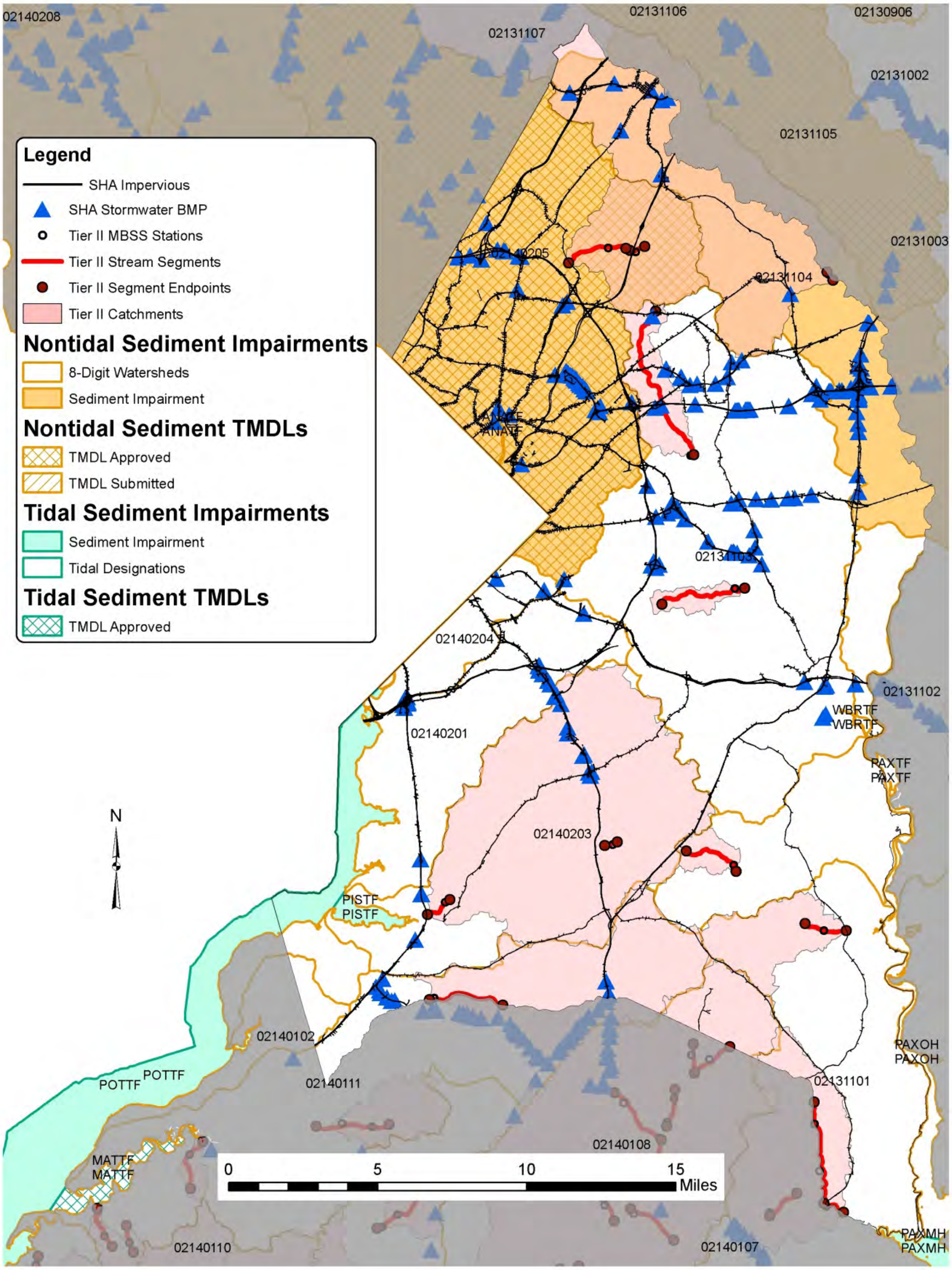


Montgomery County – Sediment

TMDL MAPPING WITH SHA IMPERVIOUS & SWM BMPs: NUTRIENTS & SEDIMENT



Prince George's County – Nutrients



Prince George's County – Sediment

TMDL MAPPING WITH SHA IMPERVIOUS & SWM BMPs: NUTRIENTS & SEDIMENT